
# MUNICIPAL WASTE DISPOSAL

## PROBLEM OR OPPORTUNITY

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## Problem or Opportunity

by

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and

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a report to the

ONTARIO ECONOMIC COUNCIL

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# FOREWARD

In cooperation with some fifteen departments and agencies of the provincial and federal governments, the Ontario Economic Council began in 1968 a study designed to maximize the recreation potentials of the 425 mile long Rideau-Trent-Severn water and land corridor between Ottawa and the Georgian Bay.

Segments of the overall study were undertaken by professors and post-graduate and undergraduate students in Ontario and Quebec universities and colleges.

Among the major land use problems uncovered was the large number of unsightly, rodent-ridden and ground water polluting private and public garbage dumps in the waterway corridor.

To determine possible courses of action to meet this threat to the environment, the Economic Council, supported in part by the Canada-Ontario Rideau-Trent-Severn study group and the federal Ministry of Transport, commissioned a study of municipal waste disposal systems by Drs. J.H. Brown and R.H. Clark of Queen's University.

Not only did these members of the University staff have a significant background of knowledge in engineering and chemistry but their physical location in Kingston in the Rideau area made it possible for them to examine at close hand a number of the more serious disposal problems which had been observed during the initial surveys.

In this research project, moreover, Drs. Clark and Brown had the full cooperation of the Kingston-based staff of the Waste Management Branch of the Ontario Department of Energy and Resources

Management.

It is the belief of the Ontario Economic Council and of the Canada-Ontario Rideau-Trent-Severn study group that this report makes a worthwhile first step toward systems of waste disposal and recovery which will contribute not only economically but ecologically in the years immediately ahead.

William H. Cranston
Chairman

January, 1971

QUEEN'S UNIVERSITY
KINGSTON, ONTARIO

January 15, 1971

Mr. W.H. Cranston
Ontario Economic Council
950 Yonge Street
TORONTO 5, Ontario

Dear Mr. Cranston:

In accord with our agreement of June 15th, 1970 we submit herewith a report titled 'Municipal Waste Disposal: Problem or Opportunity'.

First, we have assumed for our analyses that solid waste disposal will be controlled in a firm and consistent manner throughout Ontario under the Waste Management Act (1970) though this is unlikely for several reasons. One is that the regulations established under the act necessarily provide room for judgement; another is that the costs arising from strict control may be intolerable, especially for small communities. However, it would have been quite unrealistic to anticipate and provide for the numerous decisions that might develop. Instead this report presents the costs and other effects that could be generated by strict regulations and so it should be helpful to a community that is attempting to improve its disposal system.

A second feature of the report is its apparent limitation to communities of less than about 100,000 population. This limitation was deliberate, as you know, because the study was considered especially necessary for the smaller Ontario centres which represent a large portion of the province's population. However, the results show that costs for communities of 100,000 will be near the minimum levels achievable through large-scale operations so the cost comparisons of the report should be useful well beyond the population ranges considered.

Third, in the title of this report we have attempted to identify a policy that underlies any reclamation system. Wastes once destroyed are lost; reclaimed wastes are available for development into useful and hopefully profitable items. We had hoped that a reclamation system would appear profitable; however, we could show only that under the worst of conditions a reclamation system will be at least competitive with other systems at their best and in most cases will be preferable to most others. Moreover, opportunity for new products and better markets will still exist in a reclamation system and thus we plead that the aspect of opportunity should be emphasized.

Finally, we wish to commend to you several people who have contributed to this study and whose contributions are not specifically identified. These include Mr. Paul E. Davidson, Regional Engineer of the Kingston Regional Office of the Waste Management Branch, Mr. H. Elliot Dalton, Executive Director of the Glass Container Council of Canada, Mr. D.P. Ross, Commissioner of Public Works of the City of Kingston and Mr. D.A. Detwiler, Manager of the Altoona, Penna. Plant of the Fairfield Engineering Company. Also, in the conduct of the investigation and preparation of the report Mr. D.G. McIntyre, Mrs. Frances Hunt and Miss Joan Murray were essential colleagues.

And how do we thank our wives and families whose vacations were interrupted by garbage!

Respectfully submitted,

R.H. CLARK

J.H. BROWN

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# CHAPTER 1

## INTRODUCTION

The amount of solid waste generated in Canada this year will be sufficient to build a four lane highway raised three feet above ground level stretching from Toronto to Vancouver. Such is the magnitude of the solids waste disposal problem and the measure of Canadian extravagance in using the country's natural resources.

There are only a few countries which remain untroubled by waste disposal problems. In these, the standard of living is abysmally low, as North Americans have defined it, in terms of abundance of food, automobiles, refrigerators, disposable labour saving items, etc. and, as in most countries in the early 18th century, basic foods, metal, glass and paper are prized commodities. This represented the general condition in the world until 150 years ago. Much of the world's solid waste at this time consisted of human faeces and food wastes. These and other decomposable materials were allowed to accumulate in the streets and yards or were collected by farmers, to fertilize their fields. It is said that the carts used for this purpose were also employed for the delivery of fresh farm products. Cholera and typhus were prevalent diseases.

This unsanitary state of affairs was brought forcibly to the attention of the public in England by Sir E. Chadwick in 1842[1]. "Chadwick's conception of the essential requirements of public sanitary services was that clean water should be led into every habitable house, that faecal matter should be transported in sewers by the soiled water and that dry waste matter should be separately collected. The adoption of Chadwick's recommendations was impeded by political intrigue and opposed on economic grounds" and "it was not until after the year 1870 when a series of Public Health Acts made it compulsory for local authorities to provide communal services that

1. Lewis, R. A. Edwin Chadwick & The Public Health Movement 1832 - 1854 Longmans, 1953.

the country began to obtain the advantages of Chadwick's perception"[1]. This same perception and clear statement of ideals were undoubtedly of benefit in the development of Canadian cities.

In retrospect, many of our domestic solid waste problems were created at this time by the decision to collect dry waste materials separately. If the Garchey system or its modern equivalent, the garburator, had been invented it is certain that a man with Chadwick's insight would have insisted that all solid domestic wastes be transported together in suitable sewers. This would not only have avoided the dual problem of solids waste disposals from sewage plants and garbage cans but would have discouraged the production of many 'disposable' items and would have simplified the technical problems which now confront us. Although some communities are insisting on the installation of garburators, it is now far too late for most communities to consider the unification of the collection and disposal of domestic waste materials in this way.

Communal collection and separation of the two domestic waste streams also immediately destroyed the traditional methods of recycling waste materials and although some salvaging or recycling has been practiced, particularly during wartime periods, it is only recently that this aspect has been reviewed with the attention it deserves. Indeed the drain and the garbage can have, during the past 100 years, encouraged wasteful practices, have complicated the operation of sound reclamation systems, and have now presented Canadians with a waste disposal problem of a serious magnitude.

The concern of the young, the preaching of the prophets and the observation of grim reality has brought a public demand to halt the wasteful destruction of the environment. In response, federal and provincial governments are actively considering and enacting legislation which will be as significant as those English acts passed in 1870. It is to be hoped that much can now be accomplished to preserve our inheritance, but, without the support of all sections of the community, any solutions will remain as curiosities of technical

1. J.C. Wylie, "Fertility from Town Wastes" Faber and Faber London. (Undated)

or political endeavour. A delay of 30 years caused by political intrigue and opposition on economic grounds was unfortunate but tolerable in the 19th century. In the latter half of the 20th century such tardiness will prove to be fatal.

## CHANGES IN POLITICAL AND PUBLIC OPINION

The change in the climate of public opinion toward the degradation of the environment in the last 30 years would make a fascinating study in human behaviour. In 1940 when detergents, with phosphate, were introduced it was predicted by some that these might create technical problems in sewage disposal and eventually affect the ecology of the waterbodies into which the sewage effluent was discharged. However, detergents were introduced, were widely accepted and were produced on an ever increasing scale. In 1950 there were complaints of foam production but in the main this was dismissed by the public as a superficial effect. In 1970 the public concern is such that legislation is being introduced to limit and eliminate the phosphate content to prevent the further decay of the water bodies. The conscience and interest of the public is now such that it is extremely unlikely that a new product of this nature would find acceptance if any doubt existed of its effect on the environment. There is now a danger that the public will become over-cautious or that the pendulum of public opinion will swing again towards the state of apathy in the face of what might appear to be insurmountable problems.

Although this example has been taken from another area of waste disposal the apathy of the past and the active awareness of the present also typify the public reactions in the last decade to waste solid disposal. To those who are working in this area the change in Canadian attitude has been most remarkable and rapid in the last 12 months. As an example, it is doubtful whether any newspaper editor would have published the copy, reproduced in Figure 1.1, a year or two ago. However public attention has been largely focussed on the "pollution" aspects of solid waste disposal and government bodies have been swift to emphasise this in the form of legislation.

The course of legislation has followed that in the U.S.A.

P.D. Jones[1] notes that "Since our economy and way of life reflects so much of our neighbours' to the South it is not surprising that our awareness of social and environmental problems follow the U.S.A. with an appropriate time lag. It is of interest to note that in the U.S.A. there has been strong federal legislation dealing with water pollution for 20 years, air pollution for 12 years, but it was not until October 1965 that the Solid Waste Disposal Act was passed". In Ontario, aside from the protection afforded by the rule of the common law and the Municipal Amendment Act of 1953, there did not exist any penal provision under which prosecutions could be made for the contamination of waters. This state of affairs changed in 1956 with the creation of the Ontario Water Resources Commission which was given broad powers to deal with all aspects of water pollution as detailed in the Ontario Water Resources Commission Act. The Act provides that "the Commission may examine any surface or ground waters in Ontario to determine what, if any, pollution exists and causes thereof". The Municipal (1960), Drainage (1962), Public Parks (1960) and Planning (1960) Acts followed[2]. The Waste Management Act[3], 1970 (Bill 94) now provides for the regulation, supervision and development of waste disposal systems. All these Acts will be valued by the general public if they can be followed by their sensible interpretation and implementation. It will take time, goodwill and finance to attain the goals established by these Acts, hopefully, without the undue wasteful extravagance of creating new bureaucratic empires or fostering academic exercises.

It will be noted that, as in the U.S.A., the regulation of solid waste disposal has been the Cinderella of environmental programs. The new Ontario Waste Management Act marks the beginning of a new era for the Province but the long period of neglect and the lack of experience in this field will cause inevitable delays in its practical implementation. However, the reorganisation of the Ontario government bodies to provide unified direction of the Ontario Water Resources

1. Jones, P.D. Engineering Journal 52 p. 31. June 1969.
2. See Legal Controls of Pollution in Great Lakes Basin — Henry Landis reprinted from Canadian Bar Review. March 1970.
3. See Appendix A

# Nine useful tips on pollution

**(Editor's Note: The following tips for helping stop the mushrooming spread of pollution in North America are reprinted from The Plain Truth, a magazine published in California. Although the statistics relate directly to the United States, they are comparable to those of Canada.)**.

**1—DON'T LITTER.** Teach your family not to litter — from the car, sidewalk, campsite, at work, school or home. It costs 30 cents of your tax money to pick up each roadside beer can (this does not include disposing of it), and the average mile of highway has 590 such beer cans — and 770 paper cups, 730 cigarette packs, 360 bottles, and 90 beer cartons. Motorists drop 15,000 pieces per mile per year in the United States. What a savings of scenery AND money if we ALL QUIT LITTERING!

**2—DON'T USE NON-DEGRADABLE PACKAGING.** You, the consumer, have unlimited power to change the packaging industry. The plastic bags which choke fish and fowl to death, the styrofoam packaging and plastic containers which defy destruction, the plastic beer can loops which have choked sea birds to death, and all forms of "immortal plastics" which are used only once then discarded, can be used NOT AT ALL if enough people refuse to buy products contained in them.

**3—BUY ONLY DEPOSIT BOTTLES.** Each returnable-type bottle is used to make 19 round trips before retiring. Most of today's bottles are junked after one usage. The power of the consumer has already been displayed here, as the bottle industry has changed their $7.5-million advertising program from stressing no-deposit bottles to stressing DEPOSIT bottles.

**4—TEACH THE CLEANLINESS HABIT** to your children, from infancy upward. If children have the habit of picking up after themselves, throwing things into the wastebasket ONLY, not throwing away items that are STILL USABLE, they will not increase the "per capita" trash that experts are predicting by 1980.

**5—PICK UP LITTER.** Of course it would be impossible for just a few people to pick up all the litter. But you can make your world neater than when you found it. Pick up litter around your home, your yard, your office, your school, your campsite or motel room; don't throw garbage under your theatre seat or basketball bleacher.

**6—BUILD LIFE INTO YOUR CAR.** Over seven million cars are junked annually in North America, many of them abandoned by the roadside. That's two tons of pollution for each car that can be prevented by a little care. The average car coming out of Detroit has a total life-span of six years (it was 10 years a decade ago). Much of this is OUR fault. With careful driving and maintenance, and limiting our trips to the necessary ones, we could double the life of our cars. And when it wears out, sell it to a steel scrap agent, DON'T ABANDON IT!

**7—START A COMPOST HEAP.** Less than one per cent of municipal trash is eventually composted, but a much larger percentage of your household trash could and SHOULD be. Organic materials — egg shells, meat by-products, fruit and vegetable waste, etc. — should be returned to the soil by natural means. Learn the principles of composting and build a compost pile in your backyard. But be careful to follow proper health rules in composting. Check with city authorities for local regulations.

**8—BUILD CRAFTSMANSHIP.** If YOU work in a factory, or if you women make clothes or crafts at home, build a long life into what you make. If ALL our manufactured products were constructed with care, a great number of TV sets, clothes, cars, appliances, and other prematurely defective items would not enter the trash heap so soon.

**9—RECYCLE AS MANY ITEMS AS YOU CAN.** This applies to a multitude of items. Various companies buy old no-deposit bottles or aluminum beer cans for ½ cent each. Other organizations have "paper drives." If your clothes, toys, or furniture are old but usable, don't "junk them," but contribute them to some charitable group which can continue USING the items. Before junking any item, ask yourself, "Can this be used again?" Once it enters the garbage can, nobody uses it!

FIGURE 1.1: RECENT NEWSPAPER ITEM

Commission, the Air Management Branch and the Waste Management Branch within the Department of Energy and Resources Management is most encouraging. Significant progress has already been made by the Waste Management Branch under the direction of Mr. J. Heaman. The importance of this branch is fully recognised by the Minister of Energy & Resources Management, the Honourable G.A. Kerr. In a recent address[1] he said "I regard the problems of garbage disposal and of industrial waste, in particular, as matters which rate top priority in the efforts of my department to introduce effective anti-pollution measures in Ontario".

With this favourable climate of public and political opinion there is a need for studies to guide the practical implementation of our newly stated ideals. This study, commissioned by the Ontario Economic Council, attempts in part to satisfy the need.

## THE NEED FOR A COMPREHENSIVE REVIEW

A recent survey of the garbage disposal systems of the Rideau district has revealed that approximately 90 percent of these systems are unsatisfactory[2]. With the exception of the systems operated by the larger cities this conclusion could probably be made for most communities which operate a garbage dump which is often euphemistically termed a sanitary landfill project.

This describes the state of affairs for the disposal of garbage but since this waste is only a fraction of the total solid waste in Canada it would seem to suggest that a review of other solid waste disposal practices would be in order.

Ignorance and neglect has resulted in a problem which has reached critical proportions in the U.S.A.. In an excellent report by Golueke and McGauhey[3] on the nature of the solid wastes problem in the U.S.A., it is stressed "that citizens and public officials have historically shown little interest in investing money in solid waste

1. Metropolitan Toronto Region Industrial Waste Symposium. January 27, 1970.
2. Guelph Study for the Ontario Economic Council
3. Golueke, C.G. and P.H. McCauhey. Comprehensive Studies of Solid Waste Management. First Report. SERL Report 67-1 Berkeley Sanit. Eng. Research Lab. Univ. of Calif. May 1967.

management; that unplanned and uncoordinated urban expansion has brought the urban, suburban and rural sectors of many communities into intimate contact; that solid wastes management has become a regional problem involving the whole spectrum of wastes produced by industrial, agricultural and domestic utilization of resources and products rather than of domestic refuse alone; that our national economy depends to an important degree upon the generation of wastes; that the technology of production of consumer goods is not significantly concerned with their ultimate disposability while the technology of disposal has not been related to the total wastes except in the most primitive way; and that ignorance of the problem and its feasible solutions persists at all levels in society".

If this statement does not apply in its entirety in Ontario today it could certainly describe the situation which will develop in the next decade unless a comprehensive evaluation of the overall problem is undertaken.

## CONSERVATION OF RESOURCES

The preservation of the total environment involves total conservation but this is impossible at the present population levels. Nevertheless, the cause of conservation must be accorded far greater attention than that now given to pollution. The elimination of gross pollution of the land, water and air only partly serves this ultimate cause. Long before man is buried in garbage or suffocates by sulphur dioxide he will die in large numbers by starvation, lack of adequate housing and disease brought about by the exhaustion of the natural resources on a national or global scale. Under these circumstances it is difficult to believe that Canadians will choose to live in a profligate manner in a world for which mass starvation is confidentally predicted and in which natural resources will be at a premium.

The critical demands to be made on natural resources and the extravagance of life on the North American Continent, is underlined by the following quotation:

> "If present trends continue" forecasts Hugo Fisher, administrator of the Resources Agency of California, "the United States, within 15 years will have about 9 1/2 percent of the world's population. At this time this 9 1/2 percent will be consuming some 83 percent of all the raw materials and resources produced by the entire world"[1].

There are already signs that heavy demands will be made upon Canada to supplement the U.S.A.'s dwindling reserves of water, gas, oil and minerals.

As a further measure of North American extravagance, individual Canadians collectively 'throw away' at least 25,000 tons of solids each day. This, however, represents the 'tip of the iceberg' since five to ten times this quantity is rejected by the commercial and process industries as indicated by Figure 1.2.

To a nation that has matured on the concepts of exploiting the limitless natural resources, the homily of "waste not, want not" will be difficult to convey. However, at the root of the solid waste disposal problem is the need to convince the public that our resources are being expended at an alarming rate and that there will be no magical scientific cure for an ecological disaster. It is possible that the recent lesson of the pollution crisis will help to avoid a conservation crisis and 'preventative', in contrast to 'corrective', legislation will be passed. Perhaps it is not too fanciful to envisage a "Resources and Reclamation Act" which will recognise that waste is an inevitable end product of the utilisation of our resources, which will regulate the development of new products and industries and which will encourage the recycling or reuse of materials.

Thus, there is an immediate need to study not only the means for a pollution-free disposal of wastes but also the more complex issues involved in the control of the processes which generate these wastes and the means for reclaiming and reusing them.

1. 'Moment in the Sun'. Robert Rienow & Leonar Train Rienow p. 20, 1970. Ballantine New York.

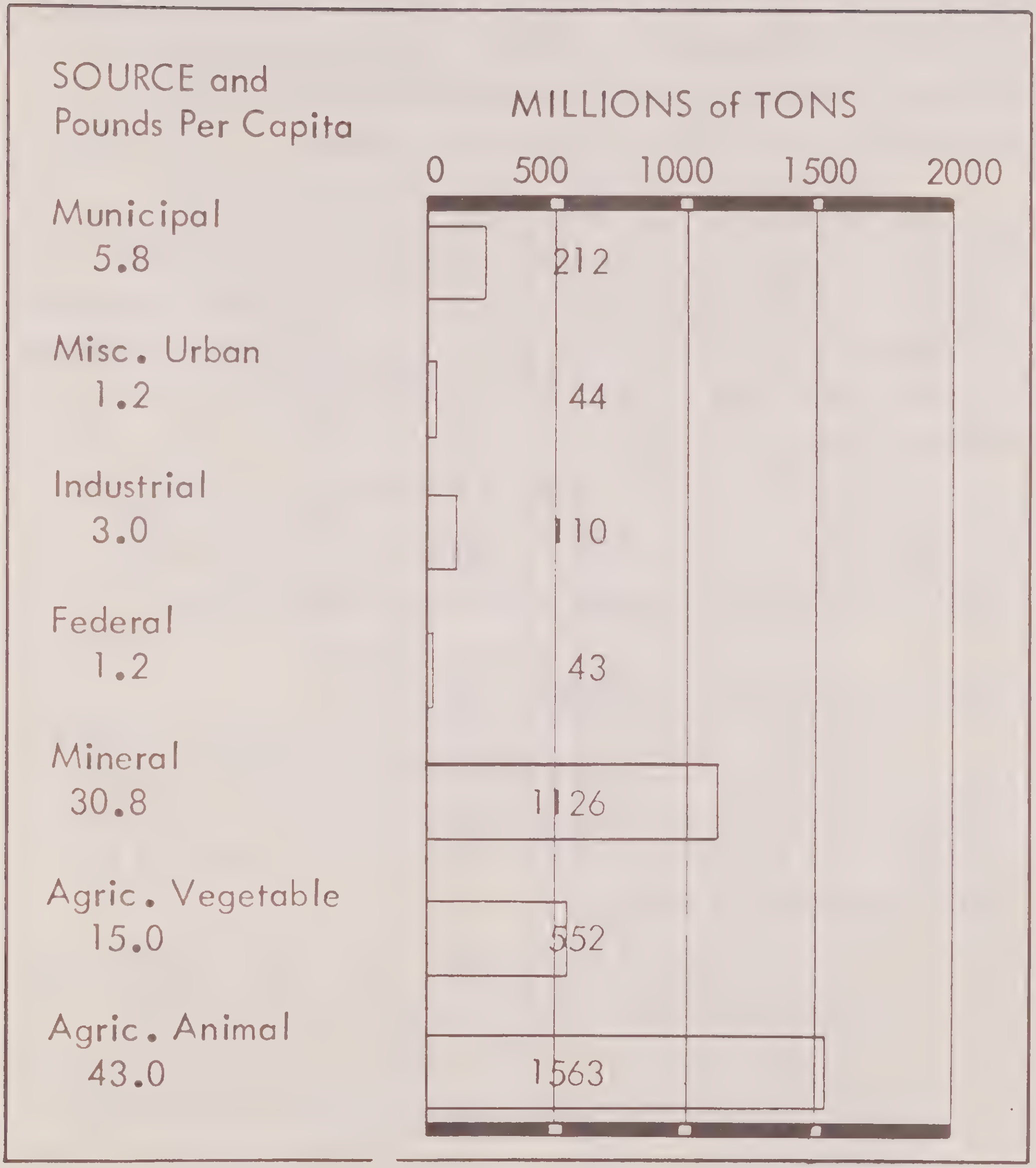



FIGURE 1.2: SOLID WASTES GENERATED BY SEVEN MAJOR U.S. SERVICES IN 1967
(After Office of Science and Technology, Washington, D.C.)

## ORGANIZATION

It is not difficult to assemble a list of all the parties in Canada interested in the waste disposal problem and this is presented in Table 1.1. No attempt has been made to rank these in order of influence or importance but it should be noted that the Individual Canadian will be a key party in all future endeavours in this field.

Even without the inclusion of any sub-organisations or dependent bodies it is impossible to define clearly the means of direct meaningful communication among these parties. There is in fact considerable evidence to suggest that there is very little coordination of activities and the transmittal of technical and economic information has taken second place to statements of a platitudinous or of an emotional nature.

The need for a future study in this area should be obvious. It is to be hoped that the present study will promote this study by emphasising this aspect and by providing material which might provoke joint discussion between many of the parties concerned.

## OBJECTIVES AND SCOPE OF THE PRESENT STUDY

The general objective of the study is to contribute through a comprehensive literature survey, discussions with interested parties and the preparation of process feasibility studies to a better understanding of the state of the art, for the particular benefit of the smaller communities in Ontario.

To be more specific, the study has the following objectives:

1. To report on the state of the art by providing a review of the literature and a bibliography for the reader's future use.
2. To examine the economic and practical problems associated with the operation of the major contemporary methods of garbage disposal.
3. To examine the proposition that the disposal of domestic wastes is only part of the waste disposal problem and that in future, municipalities might be called upon to modify their existing operations.
4. To indicate the methods by which materials can be recovered from

TABLE 1.1: A LIST OF INTERESTED PARTIES

| |
|---|
| International Organizations |
| Federal Government |
| Provincial Government |
| Municipal Government |
| Manufacturers and Their Associations |
| Commercial Enterprises |
| Professional Organisations |
| Independent Consultants |
| Waste Disposal Companies |
| Educational Institutions |
| Communications Industry |
| Jurisdictional Bodies |
| Political Organisations |
| The Individual Canadian |

domestic wastes and to evaluate, in a preliminary manner, the market potentials for these materials.

5. To evaluate the practicality of recovery techniques by providing a preliminary design for a waste treatment process, using data for the Kingston area.
6. To consider the problems of collection and treatment of domestic waste from rural communities.

In the original proposal for the study submitted to the Ontario Economic Council, April 1970, three phases of study were defined:

Phase I: will consist of a technical and economic feasibility study of an experimental refuse processing plant. The goal will be to establish the design, location, flow sheet and products that should be established initially for an experimental unit, together with estimates of installation costs, operating costs and schedules for the plant.

Phase II: will consist of the construction and operation of an experimental plant. The goals will be to confirm the validity of the design considerations, to explore the values of the products, to provide design criteria and data for other plants, to prove markets, to identify potential new products and in general to establish the validity of the original concept.

Phase III: will evaluate the applicability of the process in other locations and the economies afforded by central processing units which might include relatively sophisticated equipment for reprocessing some of the more valuable constituents.

The scope of this report is in accordance with that defined for Phase I but has been broadened in keeping with the more precise definition of objectives. In particular, this report deals with:

1. The background and need for increased activity in the solid wastes disposal field.
2. A bibliography of the more recent and important literature in the solid waste field.
3. A review of existing methods for the disposal of domestic solid

wastes.

4. A review of methods now under development for the disposal of domestic solid wastes.
5. A preliminary design for a disposal system suitable for a community of the size and geographical locality similar to Kingston, Ontario.
6. A preliminary evaluation of the market for products obtained from the proposed system.

The broad scope of this report has limited its depth in certain areas. It was not possible to consider the effects of the inclusion of other wastes in the proposed system, to prove markets, to identify new products or to explore the variations in circumstance or individual designs for other communities in Ontario.

In the hope of reducing the material covered in this report to a concise and readable form it was decided to present the alternative systems of disposal as a series of feasibility studies. Emphasis has been placed on the economic aspects wherever possible since these not only indicate the possibility of public acceptance but also the areas which will be fruitful for further research and development.

# CHAPTER 2

## THE PROBLEM

The problems which beset a waste management engineer might be described as good ingredients for an engineer's nightmare. The raw material for the process varies in quantity and quality; there is a lack of design data and engineering experience; the market for the products is unexplored and the form of his final design will be strongly influenced by public and political pressures. A review of these problems would appear to be necessary before evaluating the solutions.

### LACK OF CANADIAN EXPERIENCE

The history of neglect of the technology of waste solids management leaves a legacy of lack of detailed statistics, a lack of technology and trained manpower, a wealth of prejudice and a variety of critical disposal problems.

The magnitude of the problem in Canada cannot be compared to that in the U.S.A., where a crash research and development program has been started, headed by the U.S. Department of Health, Education and Welfare. The titles of the research projects sponsored by this department between 1965-70 provide some appreciation of the data and knowledge which is now being developed[1]. This information will be of considerable benefit to Canadians but Canada, and Ontario in particular, must also consider the additional factors of climatic extremes, dispersed populations, and seasonal variations in population.

In comparision with the U.S.A., land for garbage disposal generally is at a premium in Canada only in cities and

1. See Appendix C.

other urban centres. Thus the improvement in garbage disposal methods encouraged by Bill 94 can only be justified for rural communities in terms of health, pollution abatement, aesthetics and the recovery of materials. As in the U.S.A. the most contentious problem is the choice of a location for a landfill operation, a transfer station or a disposal system. A garbage operation of any kind is not welcomed by neighbouring property owners and, in some instances, forms the mainspring for change; it will, in the future, create difficulties in properly locating even well designed systems.

The immediate problems as they concern this study are the lack of data, the absence, except in the larger centres, of Canadian experience in operating the newer disposal systems and, above all, in terms of acceptability of the study, the prejudice which exists in favour of destruction or permanent disposal of this waste stream.

A further inherent problem is that events will be allowed to move too swiftly; as a result, too many studies will be commissioned, too many 'new experts' will be consulted and the financial resources will be wasted or committed before a planned program of development on a community or provincial basis can be achieved. The HEW Department of the U.S.A. has spent vast sums in research projects and in establishing and operating prototype plants. It would be folly to repeat this work or to fail to take advantage of the results.

It is inevitable that for this study, data will need to be 'synthesised'. It will also be assumed that prejudice will not influence the detailed examination of this study's recommendations.

## THE COLLECTION SYSTEM

This study is concerned with the processing of domestic waste and a detailed analysis of collection systems cannot be undertaken. However, there are numerous aspects which influence the method of treatment and are pertinent as problems for future consideration.

First, as mentioned in the Introduction, Chadwick's concept of separating domestic wastes at the source has compounded the collection and treatment problem. If, for example, all putrescible wastes could be segregated at the source and treated together, one of the major

problems would be solved since the remaining solid waste would be inert and odourless, and present only minor health and pollution hazards. Furthermore, the solid wastes could be more easily reclaimed or disposed of. This suggests that in new urban areas consideration might be given to the compulsory installation of garburators to enable the biodegradable wastes to be treated together with sanitary wastes. Further, for existing communities where the sewage systems cannot be readily modified, regulations might be made to ensure the segregation of the putrescible and inert fractions upon collection. Both of these means for separation of the biodegradable and putrescent fraction of domestic garbage have been operated in the U.S.A.

The next problem arises from the fact that, in general, material is more easily dispersed than collected. A simple example of this tenet is the fact that it took one hundred men four days to pick up the litter from a recent 'walkathon' in Toronto whereas the total amount of food and other material carried by the walkers could have been distributed from one truck by ten men in one hour. This same problem is reflected in the costs of collection and treatment of domestic wastes; of the total costs for 'garbage disposal', 70-80 % are incurred for collection. Thus, at the present time, many communities expend approximately $8/ton for collection and 2 to $3/ton for disposal. As a result, there is a tendency to regard the collection costs as unavoidable and exert tight control on the 'disposal' charge. A reversal of this policy is desirable if significant improvements are to be made in 'disposal' methods and a review of collection procedures and methods is clearly warranted.

Yet another problem is created by the community approach to the collection system, in which it is assumed that each community shall deal with its own wastes. This assumption needs to be questioned and a study should be made of the economics of collection on a regional basis and the establishment of large effective treatment centres. Data presented later in this report argues strongly in favor of such a study.

The constitution and method of collection of domestic waste has an important bearing on the operation and costs of the disposal system. For the purposes of this study two cases will be considered: for

segregated and for unsegregated wastes. It will also be assumed that, in future, communities will consider the overall costs and benefits, and not merely compare the disposal costs of different systems, some of which offer no permanent solution. This change of attitude might even lead to the adoption of an 'ideal' solution in preference to a less expensive proposal which does not fully satisfy the aesthetic and environmental concerns.

## POLLUTION, HEALTH AND PUBLIC ACCEPTANCE

The pollution problems involved in the disposal of domestic wastes are well recognised but are still ill-defined in technical terms. For example, the pollution of the watershed by the leachate from sanitary landfill sites is recognised and Bill 94 ensures that sites will be inspected with this in mind. However, very little is known, although research has been started on this aspect[1], concerning the composition and quantity of leachate to be expected and the influence of degree of compaction or disintegration of the buried waste material. It is certain that the decomposition process takes many years and that poorly sited dumps or landfill sites present a pollution hazard of long duration; it is not known how this period is affected by the prior pulverisation of the waste. Some authors appear to believe that the decomposition is more rapid and others that it is retarded.

Air pollution which sometimes arises from spontaneous combustion of 'landfill' material will now probably be a matter of historic interest but the operation of incinerators is still of concern. The complete purification of the gaseous products from an incinerator is impossible to achieve and, as the air pollution standards are refined, the costs of pollution control equipment for incinerators might increase to a point at which this method of disposal will lose favour except in special circumstances.

With the prospect of strong but wise enforcement of the Pollution Control Legislation in Ontario there is reason to believe

1. Waste Management Branch, Ont. Dept. Energy and Resources and by the University of Wisconsin.

that the pollution aspect could be of secondary importance in the next decade. Since pollution control also should ensure proper consideration for the welfare and health of the population this requirement might also be presumed to be simultaneously satisfied. However, the handling, transport and processing of domestic wastes is a continuing health problem and must be carefully supervised and regularised. With a certain degree of optimism, it might be presumed that pollution and health problems can be solved. The long term problem is then to determine the most satisfactory method of treatment, bearing in mind that conservation of land and other natural resources must be balanced against the cost to the population in terms of 'standard of living' as well as direct charges for waste management.

During the next decade, decisions will need to be made which will have a long term effect. The public are prepared to listen to arguments for the aesthetic and for the conservation of the natural resources. How much the public is willing to expend to satisfy the new ideals is a question that demands an answer. Perhaps only the politician will "know for sure" when all the alternatives are presented and fully explained. At this stage, therefore, it must be assumed that all possible solutions must be considered even those in the state of development for which detailed cost estimates and feasibility cannot be firmly established.

## THE COMPOSITION OF THE SOLID WASTE

The variability of composition with the season of the year, from year to year and between countries and even between communities has been mentioned by most investigators. This presents a major problem for a treatment and recovery plant. Few industrial processes are required to operate effectively with such a variation in feed composition. The quantity of material to be handled also varies from month to month, from community to community, and it is also increasing on a per capita basis from year to year. Before the various processes can be considered a more detailed analysis of these problems is necessary.

Domestic waste is a complex mixture of many materials and

articles. Its variability by community is well illustrated by Table 2.1 which presents overall composition data from a number of sources. The analyses have been reported using the system of classification defined in the SERL report.

Some degree of the variation in the analyses might be ascribed to the interpretation of the different, but undefined classification systems used by different investigators. From the point of view of public health, garbage, the most objectionable fraction, constitutes only ten to fifteen percent of the total in North America, whereas the high consumption of paper products is clearly reflected. Specific data for small Canadian communities is not available and it has been assumed for the purposes of the feasibility study that it will be within the ranges indicated in Table 2.1 for other North American communities. An estimated composition has therefore been accepted and is given in Table 2.2.

The water content of domestic wastes is an item of critical importance in comparing costs of disposal and evaluating processes which utilise the calorific value of the waste but only rarely is this figure reported or recorded. Thus, for example, although Kingston has recorded tonnages of waste handled, no estimate is made of the moisture content. This figure could vary from ten to fifty percent on the wet basis and will most certainly be affected by the method of collection, climatic conditions and the dry composition of the waste. An approximate figure of twenty-five percent, on the dry basis, has been assumed to be a reasonable average for Ontario.

Of greater interest is a knowledge of the detailed composition of the waste. The broad categories of items which have been defined provide no indication of possible health hazards or the physical form of the items. Recognising this, Galueke and McGauhey[1] undertook a comprehensive survey of the individual items, their form, the decomposition products and the resulting hazards. Table 2.3 provides a summary of their findings for domestic waste. The precise distribution of the items listed in this table would be of value but considerable seasonal and regional variation is to be expected.

1. SERL Report No. 69-1.

TABLE 2.1: COMPOSITION OF DOMESTIC WASTES

| SOURCE | PERCENT BY WEIGHT - DRY BASIS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | METALS | CLOTH | PLASTICS | RUBBER | GLASS | WOOD | GARBAGE | PAPER | INERTS | TOTAL |
| SAN DIEGO[1] | 9.15 | 3.84 | 0.32 | 5.13 | 9.95 | 8.0 | 0.41 | 50.74 | 22.45 | 100.0 |
| MONTREAL[2] | 8.6 | | 5.70 | | 3.9 | | 18.8 | 50.1 | 12.9 | 100.0 |
| CALIFORNIA[2] | 10.7 | | 1.6 | | 11.7 | | 68.4 | | 7.6 | 100.0 |
| CALIFORNIA[3] | 7.0 | 4.0 | 1.90 | 1.1 | 8.0 | 2.0 | 15.5 | 51.5 | 5.0 | 100.0 |
| JOHNSON CITY[4] | 15.0 | 1.3 | | 1.5 | 7.0 | 0.3 | 22.8 | 59.8 | 0.6 | 107.5 |
| GAINSVILLE[4] | 7.55 | 2.10 | | 2.77 | 6.54 | 0.13 | 21.85 | 53.53 | 5.56 | 100.0 |
| MOBILE[5] | 8.0 | 0.80 | | | 7.0 | | 35.6 | 39.7 | 8.9 | 100.0 |
| RALEIGH[6] | | | | | | | | | | |
| (i) Income >$7,000 | 6.7 | 2.07 | | | 14.4 | | 26.36 | 47.23 | 2.07 | 100.0 |
| (ii) Income <$7,000 | 7.9 | 4 13 | | | 11.0 | | 35.94 | 39.43 | 2.90 | 101.3 |
| TORONTO[7] | 5.9 | 1.50 | 2.60 | | 8.0 | 1.10 | 38.90 | 39.50 | 2.50 | 100.0 |

[1]Hoffman, D.A., Environmental Science & Tech., Nov. 1968, p.1023.

[2]Alane, A., Compost Science 8 (1) 1967.

[3]S.E.R.L. Report 69.1, 1969.

[4]Westerhoff, G.P., Public Works, Nov. 1969.

[5]Moulton, G.L., Compost Science 2 (1) 1961.

[6]Galler, W.S., Compost Science, Aut. 1969 p.12.

[7]Report and Technical Discussion on Refuse Disposal for the Municipality of Metropolitan Toronto, May 1967.

TABLE 2.2: APPROXIMATE COMPOSITION OF DOMESTIC WASTE

| MATERIAL | PERCENT BY WEIGHT - DRY BASIS | | |
|---|---|---|---|
| | Sub Item | Percent | Total |
| METALS | - | - | 8.3 |
| CLOTH | - | - | 3.6 |
| PLASTICS | Polyethylene | 1.25 | 3.1 |
| | P.V.C. | 1.00 | |
| | Polystyrene | 0.65 | |
| RUBBER | - | - | 1.0 |
| GLASS | - | - | 8.3 |
| WOOD | - | - | 2.0 |
| GARBAGE | Cereal & Grain | 0.5 | 15.5 |
| | Meat | 2.3 | |
| | Oils & Fats | 2.3 | |
| | Fruit | 1.5 | |
| | Vegetables | 2.3 | |
| | Egg Shells, Bones Coffee Grounds | 2.8 | |
| | Tree Leaves | 1.5 | |
| | Lawn Trimmings | 1.0 | |
| | Plants | 1.3 | |
| PAPER | Stationery | 2.88 | 53.0 |
| | Books & Magazines | 7.0 | |
| | Newsprint | 9.75 | |
| | Absorbent paper | 1.03 | |
| | Paper Dishes | 1.03 | |
| | Brown Wrapping | 5.77 | |
| | Coated Paper | 1.54 | |
| | Cardboard | 24.0 | |
| INERTS | - | - | 5.2 |
| WATER | As percent of Dry Weight | 25 percent | |
| CALORIFIC VALUE | Wet Basis | 4800 Btu/lb | |

| Source<br>1 | Type<br>2 | Environmental Fate of Material and Conversion Products in Relation to Disposal Method: Incineration<br>3 | Sanitary Landfill and Composting<br>4 | Identified Public Health Significance (at present (1968) stage of project)<br>5 | Suggested Research Needs<br>6 |
|---|---|---|---|---|---|
| | | METALS (Approximately 7% of Total) | | | |
| Cans<br>Aluminum foil<br>Kitchenware<br>Cutlery<br>Appliances<br>Furniture<br>House fixtures<br>Razor blades<br>Tools, nails, etc.<br>Toys<br>Clothing hangers<br>Blinds and shades<br>Pails<br>Bottle caps<br>Ash trays<br>Plumbing fixtures<br>Luggage<br>Batteries<br>Shoes<br>Doormats<br>Crates<br>Paint<br>Paper<br>Glass<br>Pens<br>Lamps (incandescent and fluorescent)<br>Radio sets<br>Television sets<br>Miscellaneous other electronics<br>Cloth<br>Leather goods<br>Mineral "ash"<br>Miscellaneous junk | Iron (Fe)<br>Aluminum (Al)<br>Tin (Sn)<br>Zinc (Zn)<br>Lead (Pb)<br>Copper (Cu)<br>Silicon (Si)<br>Carbon (C)<br>Nickel (Ni)<br>Magnesium (Mg)<br>Cadmium (Cd)<br>Selenium (Se)<br>Vanadium (V)<br>Tungsten (W)<br>Beryllium (Be)<br>Mercury (Hg)<br>Titanium (Ti)<br>Sulfur (S)<br>Silver (Ag)<br>Gold (Au)<br>Chromium (Cr)<br>Calcium (Ca)<br>Sodium (Na) | 1. Appear in metallic form in residue to reclamation or landfill: Fe, Al, Pb, Zn, Cu.<br>2. Appear as relatively inert compounds in ash to landfill: FeO; $Fe_2O_3$; $Al_2O_3$; $SiO_3$; $CrO_2$, $CrO_3$; $Cu_2O$; CuO; ZnO; SnO; $V_2O_2$, $V_2O_3$; $V_2O_4$; NiO; $Ni_2O_3$; $Ni_3O_4$; CdO; $Cd_2O$; PbO; $PbO_2$; $Pb_3O_4$; $Pb_2O_3$; $Pb_2O$; SeO; HgO; $TiO_2$; $Ti_2O_3$; MgO; CaO.<br>3. May appear as particulate matter in stack discharges. (See 2, above.)<br>4. May appear as vaporized metal in stack discharges: Al; Be; Zn; Hg; Se; Pb; Cd.<br>5. Appear as gases in stack discharge: $Co_2$; CO; $SO_2$; $SO_3$.<br>6. Appear in stack discharge as by-products of incineration process: N-oxides. | 1. Remain in landfill as inert or relatively inert compounds unless fill eroded by surface runoff: Uncombined metals; $Al_2O_3$; $Al(OH_3)$; FeO; $FeO_2$; $Fe(OH)_2$; $Fe(OH)_3$; $CrO_2$; $Cr_2O_3$, $Cr(OH)_2$; $Cu_2O$; CuO; $Cu(OH)_2$, SnO; ZnO; $Zn(OH)_2$; $V_2O_2$; Be; BeO; NiO; $Ni_2O_3$; Ni(OH) ; CdO; $Cd_2O$; $Cd(OH)_2$; PbO; $Pb_2O_3$; $Pb_3O_4$; $Pb_2O$; Se; $SeO_2$; Hg; HgO; $TiO_2$; MgO; $Mg(OH)_2$; $Ca(OH)_2$, $CaCO_3$.<br>2. May leach to groundwater: Ca and Mg sulfates; Fe, Ca, and Mg bicarbonates, $CO_2$; also oxides of Sn, Zn, Cu in acid water.<br>3. Escape to atmosphere: essentially none. | 1. Particulate lead in air may cause chronic intoxication; soluble lead compounds are cumulative poisons. Percentage of lead in air due to disposal of domestic wastes not significant.<br>2. Particulate beryllium produces pulmonary fibrosis. Hazard to workers in solid wastes disposal possible; hazard to public from this source unknown.<br>3. Inhalation of cadmium oxide dust or fumes may cause pulmonary endema or hemorrhage and can be fatal. Hazard to public from solid wastes disposal unknown.<br>4. Inhalation of zinc fumes or finely divided zinc oxide may result in "metal fume fever"" and damage to epithelial cells in the respiratory tract. Hazard from domestic fraction in relation to industrial fraction of wastes unknown, as is overall hazard of zinc in solid wastes.<br>5. Particulate matter reduces clarity of atmosphere. Heavy metals (e.g., Cr and Ni) may produce cancer.<br>6. CO and oxides of nitrogen and sulfur known air pollutants. Relative contribution of incineration of domestic metal wastes probably insignificant.<br>7. Compounds of Cr, Cu, V, known to be toxic. Oxides of Fe, Cu, Zn, Sn toxic. Contribution from domestic wastes probably not important.<br>8. Mercury vapor deadly. Trivial constituent of domestic metal wastes. | 1. Investigation of exposure of refuse "tippers" and equipment operators to beryllium might be useful.<br>2. Analysis of incinerator stack discharges for types and amounts of various metallic compounds needed, including degree of removal by various fly ash and particulate control devices.<br>3. Medical research is needed on toxicity levels of compounds of metals such as cadmium and selenium which are coming into wider use in the U.S.<br>4. Studies needed to establish existing background level of dangerous metal compounds in urban concentrations - possibly on methods of making such analyses.<br>5. Extend current studies on toxicity of metals and metal oxides to animals (men) and plants. |

TABLE 2.3: COMPONENTS OF DOMESTIC WASTE (after SERL Report 69-1)

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| CLOTH - Natural and Synthetic Fibers (Approximately 4% of Total) | | | | | |
| Rags<br>Furniture upholstery<br>Rugs, carpets<br>Apparel<br>Curtains, drapery<br>Bags<br>String, twine, rope<br>Luggage<br>Shoes<br>Toys<br>Doormats<br>Tires | Rayon<br>Dacron<br>Dekton<br>Other synthetic fibers<br>Cotton (cellulose, 83%)<br>Wool (keratin - C, 50%; H, 7%; O, 22%; N, 17%; S, 9%)<br>Linen (cellulose, 82%)<br>Silk (C, 48%; H 6%; N, 20%; O, 26%)<br>Hemp<br>Sisal | 1. Appear as gases in discharge: $CO$; $CO_2$; $SO_2$; $S_2O_3$; $SO_3$.<br>2. May appear in stack discharges as products of synthesis and incomplete combustion: aldehydes; ketones; low molecular weight hydrocarbons; HCl chlorinated hydrocarbons; polynuclear hydrocarbons.<br>3. Appear in stack discharge as by-products of incineration process; N-oxides.<br>4. May appear as particulate matter in stack discharge. | 1. Remain in landfill as inert or relatively inert materials:<br>a. Materials fabricated of synthetic fabrics.<br>b. Oxidized and reduced minerals in "natural" fibers.<br>2. Remain in landfill by incorporation into microbial protoplasm: $NH_4^+$; reduced sulfur compounds: C; P; K.<br>3. May leach out to groundwater: $CO_2$; aldehydes; ketones; organic acids; sulfates; phosphates; $NH_4^+$; $NO_2^-$; $NO_3^-$.<br>4. Escape to atmosphere: $CO_2$; $CH_4$; volatile short-chain fatty acids; $N_2$; $NH_3$; $H_2S$; mercaptans ($N_2$ and $CH_4$ formation unlikely in composting). | 1. Chlorinated hydrocarbons may damage central nervous system. Amount, and hence hazard to public unknown.<br>2. Aldehydes, HCl, ammonia, oxides of sulfur, $H_2S$, and nitrogen, CO and $H_2S$, are irritants and/or toxicants.<br>3. Some low molecular weight and polynuclear hydrocarbons are carcinogenic.<br>4. Short-chain fatty acids, $H_2S$, and mercaptans are odorous.<br>5. Particulate matter reduces clarity of atmosphere.<br>6. $CO_2$ diffused in soil leads to pickup of hardness (no health significance).<br>7. Odors from landfill and composting may be nuisance in vicinity by site.<br>8. Items 2-5 significant only in vicinity of incinerator. Contribution to total air pollution is minor.<br>9. Quantitative data on item 6 unavailable, consequently hazard to public health unknown. | (See PLASTICS below) |
| PLASTICS (Approximately 1.9% of Total) | | | | | |
| Bags<br>Wrappers<br>Records<br>Dishes and utensils<br>Pens<br>Appliance cases<br>Brushes and combs<br>Luggage<br>Rain gear<br>Apparel<br>Shoes<br>Floor covering<br>Packaging | Polyethylene (38%)<br>Polyvinylchloride (32%)<br>Polystyrene (21%)<br>Polyethylene acrylate copolymers<br>Polyamide fluorocarbons<br>Polysulfides<br>Alleyl resinesters<br>Polycellulose<br>POlyalycols | 1. May appear in stack discharge as products of synthesis and incomplete combustion: HCl; halides; aldehydes; low molecular weight hydrocarbons; low molecular weight polynuclear and aromatic hydrocarbons.<br>2. Appear as gases in stack discharge: $CO$; $CO_2$; $SO_2$; $S_2O_3$; $SO_3$.<br>3. May appear as vaporized plastic in stack discharge.<br>4. May appear as particulate matter in stack discharge.<br>5. Appear in stack discharges as by-products of incineration process: N-oxides. | Essentially inert in landfill | 1. Chlorinated hydrocarbons may damage central nervous system.<br>2. Some low molecular weight hydrocarbons, particularly polynuclear and aromatic hydrocarbons are carcinogenic.<br>3. Aldehydes, halides, sulfates, HCl, respiratory irritants.<br>4. CO and oxides of sulfur and nitrogen are toxic and/or irritants in atmosphere.<br>5. Particulate matter reduces clarity of atmosphere.<br>6. Domestic refuse principal contributor of plastics to solid wastes; percent of total rapidly increasing, hence health implications of growing concern in incineration process.<br>7. Incineration products may cause odor nuisance.<br>8. Items 1-7 important in vicinity of incinerator. Contribution to total air pollution is minor. | 1. Process research needed to improve technology of incineration of plastics.<br>2. Scientific research needed to develop degradable plastics.<br>3. Environmental studies needed to evaluate the relative contribution of domestic wastes disposal and other sources of identified health-related air pollutants, particularly in local areas of significant concentrations. |

TABLE 2.3 (cont'd): COMPONENTS OF DOMESTIC WASTE

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| LEATHER ( 1% of Total) | | | | | |
| Luggage<br>Purses and Wallets<br>Apparel<br>Shoes, boots<br>Upholstery<br>Book binding<br>Machinery belts | Protein<br>Collagen<br>keratin | 1. Stack discharge: See Items 1, 2, 4, PLASTICS (above).<br>2. Appear in stack discharges as by-products of incineration: N-oxides. | 1. May leach out to groundwater: $CO_2$; aldehydes; ketones, organic acids; sulfates; phosphates; $NH_4^+$; $NO_2^-$, $NO_3^-$.<br>2. Remain in landfill by incorporation into microbial protoplasm: $NH_4^+$, reduced sulfur compounds; C; P; K.<br>3. May escape into atmosphere: $CO_2$; $CH_4$; volatile short-chain fatty acids; $N_2$; $NH_3$; $H_2S$, mercaptans ($N_2$ and $CH_4$ formation unlikely in composting). | 1. Products of disposal methods similar to those of CLOTH. Little public health significance because of small amount in domestic wastes. | See CLOTH. |
| RUBBER - Natural and Synthetic (Approximately 1.1% of Total) | | | | | |
| Tires<br>Doormats<br>Shoes<br>Tile<br>Rain gear<br>Machinery belts<br>Floor covering<br>Apparel | Natural rubber (polyterpene - long chain of isoprene residues)<br>Synthetic rubbers, e.g.:<br>Butadiene (acrylonitrile copolymer)<br>neoprene (CH = C Cl - CH = $CH_4$)<br>styrene<br>isobutylene - isoprene<br>chloroprene<br>polysiloxane polymer | 1. Stack discharge same as for PLASTICS (Items 1, 2, and 3); and for LEATHER (Item 2).<br>2. Appear in stack discharges as by-products of incineration process: N-oxides. | 1. Synthetic rubber is essentially inert.<br>2. Natural rubber breaks down extremely slowly. | 1. See Items 1 and 2, PLASTICS (above).<br>2. Dense black smoke characteristic of small incinerators burning rubber.<br>3. Odor nuisance accompanies burning of rubber.<br>4. Dust from tire wear on city streets adds to respiratory problems of urban dwellers. Quantity, hence importance unknown.<br>5. See Item 8, PLASTICS (above). | 1. Medical and environmental research needed to assess the health hazard of particulates in street dust resulting from motor vehicle tires. |
| GLASS (Approximately 8.0% of Total) | | | | | |
| Tableware<br>Bottles, jars<br>Lamps (incandescent and fluorescent)<br>Mirrors<br>Windowpane<br>Miscellaneous containers<br>Glass wool<br>Glass fiber (woven)<br>Decorative glass | "Soft" glass (e.g., $Na_2O$, CuO, $SiO_2$).<br>"Hard" glass (e.g., $B_2O_2$ - 12 %, $SiO_2$ - 81%). | 1. Appears as inert material in ash to landfill. | 1. Inert in landfill and composting process. | 1. Broken glass may be hazard to men handling solid wastes.<br>2. May be aesthetically unacceptable in compost on soil.<br>3. In open fill uncrushed containers may retain food scraps and attract vectors, or hold water in which mosquitoes breed.<br>4. Items 1 and 2, are of local significance. | 1. Technological research needed on ways to reprocess and reuse glass in order to re uce amount of wastes. |

TABLE 2.3 (cont'd): COMPONENTS OF DOMESTIC WASTE

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| WOOD (Approximately 2% of Total) | | | | | |
| Furniture<br>Picture frames<br>Boxes<br>Crates<br>Tree trimmings<br>Luggage<br>Sawdust and shavings<br>Scrap lumber | Wood<br>(Cellulose - 55%; Lignin - 24%; Pentosans - 18%; N - 0.2%; P - 0.1%; K - 0.2%; Terpenes-; Mono-; Sesqui-; Diter-; Triter-; Abietic Acids; Pimaric Acids; Esters) | 1. Appear in stack discharge as combustion products: $CO$; $CO_2$.<br>2. Appear in stack discharge as by-products of incineration: N-oxides.<br>3. May appear in stack discharge as products of synthesis or of incomplete combustion: low molecular weight hydrocarbons; low molecular weight aromatic and aliphatic hydrocarbons; polynuclear hydrocarbons; phenols.<br>4. May appear as particulate matter in stack discharge.<br>5. Appear in ash for disposal to landfill: $K_2O$; $KOH$; phosphates. | 1. May leach to groundwater: $CO_2$; aldehydes; ketones; organic acids; phenol; $NH_4^+$; $NO_2^-$; $NO_3^-$.<br>2. Remain in landfill through incor-;oration into microbial protoplasm: $NH_4^+$; C; P; K.<br>3. May escape into atmosphere: $CO$; $CH_4$; volatile short-chain fatty acids; $N_2$; $NH_3$. | 1. See CLOTH.<br>2. Amount of N-oxides from wood burning is small.<br>3. Health significance of conversion products of wood in domestic wastes is small because of low-percentage of this component.<br>4. Wood and paper may be major sources of fly ash in poor incineration; causing nuisance and loss of air clarity.<br>5. Nuisance insects (e.g., earwigs) may thrive in poor landfill.<br>6. Wood partially decomposed in composting process may serve as food for objectionable fungi and insects. May be significant in composting if use of product is widespread. | 1. No particular need for research on Wood in domestic refuse. (See DEMOLITION DEBRIS for research needs on Wood.) |
| GARBAGE (Approximately 15.5% of Total) | | | | | |
| Cereal and grain products (0.5%)<br>Meat trimmings and wastes (2.3%)<br>Oils and fats (2.3%)<br>Fruit (1.5%)<br>Vegetables (2.3%)<br>Egg shells, bones, coffee grounds (2.8%)<br>Tree leaves (1.5%)<br>Lawn trimmings (1.0%)<br>Plants (1.3%) | Protein<br>Sugars<br>Starches<br>Cellulose<br>Fat<br>Neutral fats<br>Fatty acids<br>Lignin<br>Cellulose | 1. Stack discharges same as for WOOD (Items 1, 2, 3 and 4), plus aldehydes, ketones, and acrolein. | 1. Possible leachates to groundwater: See WOOD (above); plus sulfates, phosphates, and carbonates.<br>2. See Item 2, WOOD (above).<br>3. May escape into atmosphere: $CO_2$; $CH_4$; volatile short-chain fatty acids; $H_2S$; mercaptans; $H_2$; $NH_3$. (In composting, $N_2$ and $CH_4$ formation unlikely.) | 1. Fly nuisance and danger of fly borne disease is a major public health concern with garbage.<br>2. Uncollected garbage in slums a major source of rat food; hence of rat bites and rat borne diseases.<br>3. Insect and rodent vectors of disease harbored by poorly managed land disposal may constitute an important health hazard.<br>4. Odor nuisance of garbage an important environmental factor. | 1. Environmental research on housing, slum clearance, social and cultural effect of poverty needed.<br>2. Technological research on refuse collection systems needed. |

TABLE 2.3 (cont'd): COMPONENTS OF DOMESTIC WASTE

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| PAPER (Approximately 51.5 % of Total) | | | | | |
| Stationery (bond, envelopes, ledger, etc.) (2.8%)<br>Books and magnazines (6.8%)<br>Absorbent paper ("Tissue" products) (1.0%)<br>Paper dishes (1.0%)<br>Wrapping paper - brown (5.6%)<br>Coated paper ("wax" paper, glazed paper, plastic-coated paper, cartons, containers) (1.5%)<br>Cardboard (boxes, packing, etc.) (23.4%) | Kraft<br>Ragstock<br>Sulfite<br>Sized<br>Inked<br>Wax - impregnated, glazed<br>Plastic-coated<br>Resins (urea formaldehyde; melamine formaldehyde; "natural" resins) | 1. Appear in stack discharge as combustion products; CO; $CO_2$.<br>2. Appear in stack discharge as by-products of incineration: N-oxides.<br>3. May appear in stack discharge as products of incomplete combustion or synthesis: low molecular weight hydrocarbons; low molecular weight aromatic and polynuclear hydrocarbons; phenols.<br>4. May appear as particulate matter in stack discharge. | 1. May leach to groundwater: $CO_2$; aldehydes; organic acids; phenol; $NH_4^+$, $NO_2^-$, $NO_3^-$.<br>2. Remain in landfill through incorporation into microbial protoplasm: $NH_4^+$; C; P; S.<br>3. May escape into atmosphere: $CO_2$; $CH_4$; volatile short-chain fatty acids; $H_2S$; mercaptans; $N_2$; $NH_3$. ($N_2$ and $CH_4$ formation unlikely in composting.) | 1. Paper is principal source of harmful gases and particulates which may be produced by inefficient incineration (See CLOTH, Items 1 to 5) of domestic refuse.<br>2. Phenols produce taste in water. May come from degradation of sizing and coatings in landfill or composting process.<br>3. Amount of $NH_3$, $H_2S$, and mercaptans from paper is too small to have much public health significance.<br>4. Items 1 and 2 are of major significanace in vicinity of incinerator. Contribution to total incineration is slight. | 1. Principal research needs are technological:<br>a. Control of combustion products;<br>b. Recycling, reclamation, or conversion of paper.<br>2. (See Item 3, PLASTICS.) |
| UNCLASSIFIED FRACTION (5% of Total) | | | | | |
| Soil<br>Ashes<br>Bricks<br>Tile<br>Crockery<br>Concrete<br>Miscellaneous rubble | SiO<br>Fired clay<br>Calcined CaSO<br>Cement | 1. Appear as inert material in ash to landfill. | 1. Relatively inert.<br>2. Ashes in fill may leach soluble minerals to groundwater reducing its chemical quality | (No health problems identified.) | (None suggested.) |

TABLE 2.3 (cont'd): COMPONENTS OF DOMESTIC WASTE

Furthermore, the resulting data would only be of short term value since new products are being introduced to an extent that even the percentage distribution by category might change. As one interesting example of this aspect the reader is referred to Figure 2.1. Thus, although the quantity of each item may be important in the design of a process, this lack of information must be accepted at this time. This list of items is useful, however, in estimating the practicality of certain process designs and in focussing attention on items which could cause operating difficulties.

For the purpose of this study it is assumed that all the items listed in Table 2.3 will be present and that the overall composition will be as given in Table 2.2. It is reasonable to assume, that, for the purposes of this preliminary feasibility study, departures from these values will not be large and will not unduly affect the economic considerations.

## THE QUANTITY OF DOMESTIC WASTE

Good records of annual tonnage of domestic refuse produced are difficult to find for the smaller communities in Ontario. Even the more progressive communities have only maintained an approximate record for the last few years. Data for the larger cities indicates however that the disposal rate per person is increasing as demonstrated in Figure 2.2. This same conclusion appears to be valid for smaller towns in the U.S.A. and a similar trend might be assumed for Canadian communities.

Variations in the amount of household waste are to be expected between communities. Golueke and McGaughey[1] report that "one could infer that the average daily per capita wastes, at the time of the survey was made, was around 5.3 pounds, varying from as low as 2 pounds to as high as 11 pounds". Variations in quantity and analysis have also been reported for different income groups and connected with this perhaps are the differences noted for populations in apartments and private houses. One of the most promising developments is the attempt being made by Golueke and McGaughey[1] to estimate 'multipliers' to

1. SERL Report 69-1.


The throwaway cult is undermining the panty market.

As the ad says, the summer forecast is zero below. Zero is a disposable panty found "at leading stores and on better girls."

Distributed in Canada by Phoebus Imports Inc. of Montreal, the throwaway panties have swept into Canada from Britain and Western Europe where they have become increasingly popular since their introduction about two years ago. The same company is also distributing disposable briefs for men.

To launch the product in the Ontario market, Phoebus last week started a heavy print and billboard campaign supplemented by radio commercials. Advertising was prepared by the Montreal branch of Ronalds-Reynolds and Co. Ltd. of Toronto.

Edward E. Elias, president of Phoebus Imports, said his company has an exclusive franchise for Canadian distribution of the product, which is produced by Bolton Textile Mills Ltd. of Bolton, England. The disposable panty is made of special non-woven fibre containing 20 per cent acrylic and 80 per cent viscose-rayon.

Mr. Elias described Zero as "more of a new concept than a new product." He is aiming for Canadian sales of about $1-million this year. The advertising budget is estimated at $80,000.

FIGURE 2.1: RECENT ADVERTISEMENT

provide for the prediction of the amount of the wastes from various sectors of the community.

The lack of standard terminology also causes considerable difficulty in evaluating reported figures for waste quantities. The term 'municipal waste' is frequently used to describe the combination of domestic, commercial and industrial waste which is collected by the community system. The total amount per capita is, therefore, much above the figure for domestic wastes alone.

Recent data for Kingston illustrates the care which must be taken in evaluating quantities for, as will be noted from Table 2.4, the total municipal waste can be twice the domestic waste quantity. In addition, although it is not reported in the table, the Kingston facilities also handle a further 16,000 tons/yr of solid waste from sources outside the city.

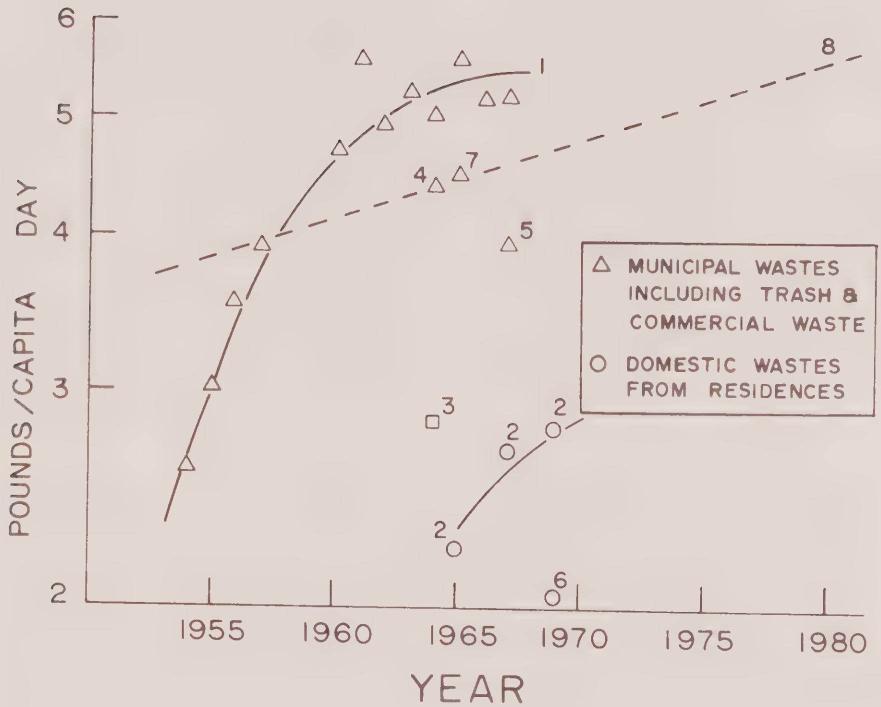
TABLE 2.4: DISPOSAL DATA FOR KINGSTON, ONTARIO

| ITEM | YEAR | | |
|---|---|---|---|
| | 1965 | 1967 | 1969 |
| City Garbage (tons) Domestic Waste | 22,750 | 27,880 | 28,000 |
| Other Refuse (tons) Commercial Waste | 25,000 | 30,000 | 30,000 |
| Population Served | 54,651 | 57,362 | 55,495 |
| Domestic Waste lbs/capita/day | 2.28 | 2.66 | 2.77 |
| Commercial Waste lbs/capita/day | 2.51 | 2.87 | 2.97 |
| Municipal Waste lbs/capita/day | 4.79 | 5.53 | 5.74 |

From the SERL Study, the amount of domestic waste per capita per day was found to be 2.04 lbs, whereas, the Kingston figure for 1969 is estimated to be 2.77. Other data in the literature indicates that the latter figure may be somewhat inflated due perhaps to the inclusion of other wastes in this city's estimate. A figure of 2.50 lb/capita/day therefore appear to be a reasonable estimate for the domestic waste fraction.

From the data presented in Figure 2.2 it would appear that the

FIGURE 2.2: RECENT WASTE GENERATION RATES FOR SEVERAL CITIES




YEAR

1. Hartford Connecticut, C. Kurker, J. Air Pollution Control Assoc. 1969 19 No. 2 p. 71
2. Kingston, Department of Works Records
3. Massachusetts, J.L. Hayden, Public Works, July 1964
4. Eastern U.S. Cities, A.S.M.E. Report, Public Works, Jan. 1966
5. U.S.A. Average, Rogers, C.A., Power, December 1967
6. California, S.E.R.L. Report, No. 69-1
7. U.S.A. Average, Michaels, A. American Cities, May 1968
8. U.S. Average, Gilbertson, W.E., Compost Science 63 1966

commercial fraction of a municipality's waste would be equivalent to 3.0 lbs per capita per day. The composition of this material is not known but for the purposes of the preliminary feasability studies it will be assumed to have a composition similar to that of domestic waste[1].

1. See p.117 et seq of this report.

# CHAPTER 3

## DISPOSAL BY SANITARY LANDFILL

Dumping and the more refined technique of Sanitary Landfill have formed the most popular methods of solid waste disposal in the past.

For many communities this might remain the cheapest and the best method of disposal although the costs of disposal will mount as suitable sites become more remote and the operations are refined to meet the new regulations. Whatever method is employed for the treatment of solid wastes a landfill operation will be required if only to dispose of valueless inert materials such as building materials, ashes and oxidised metals.

Open dumps, except for the disposal of inert material will presumably no longer be permitted. Such dumps have allowed the indiscriminate dumping of all wastes and have been a significant source of water and air pollution and a breeding ground for flies and rodents. Most of the communities now operating open dumps will be required to convert these to sanitary landfill operations or provide other means of disposal.

The regulations concerning the operation of landfill sites have now been developed by the Waste Management Branch of the Department of Energy and Resources Management and a copy of the regulations is included in Appendix A. It will be noted that the site must be selected with considerable concern for the prevention of pollution hazards to groundwater, streams and lakes and that the operation must ensure drainage of surface water or groundwater to minimize pollution resulting from leachate. The preparation and operation of the site is also given consideration but precise specifications for compaction, cell operation, daily cover and final cover are not stated. Neither do the regulations cover the disposal of sewage wastes, liquids or other hazardous materials. The regulations also fail to distinguish between

the disposal of degradable and inert waste.

Little quantitative information is available on the degradation of waste materials under landfill conditions. The degradation takes place by inorganic leaching and by biological anaerobic degradation of the cellulosic and other organic materials. It is also conceivable that some degradation of inorganic constituents may occur by biochemical routes. Inflammable gases, notably methane, are generated and the leachate contains a great variety of inorganic and organic compounds[1]. These materials, including even the carbon dioxide evolved, can provide a serious water pollution hazard[2]. The degradation proceeds very slowly and thus the pollution hazards exist for years and, meanwhile, the land remains unfit for building purposes.

The cost of a landfill operation will depend on the local conditions and requires a detailed analysis of the following factors:

(i) Population served
(ii) Quantity of refuse and type
(iii) Method of collection
(iv) Site evaluation and location
(v) Type of landfill operation (See Figure 3.1)
(vi) Source and type of cover material.

A knowledge of the approximate costs of a landfill operation will be required for comparison with other methods of disposal and for computing the costs of handling material rejected from alternative processes. An approximate cost estimate, therefore, will be attempted and the following conditions will be assumed.

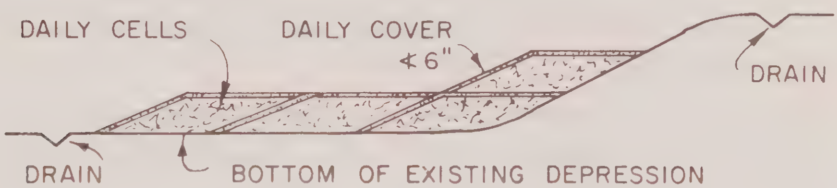
1. The Ontario regulations for a landfill operation will be observed.
2. The method of operation will be generally as illustrated in Fig. 3.2, which provides for a working face of 50 ft.
3. Preparing the site to provide cover soil or of purchase of soil for this purpose will cost $1.per cubic yard.

1. Report on the Investigation of Leaching of a Sanitary Landfill 1954, California State Water Pollution Control Board.
2. Water Pollution Hazards from refuse produced carbon dioxide. Bishop Carter and Ludwig, International Conference on Advances in Water Pollution Research Proceedings 3d 1966 VI p. 207.

# FIGURE 3.1

## MAIN TYPES OF SANITARY LANDFILL OPERATION

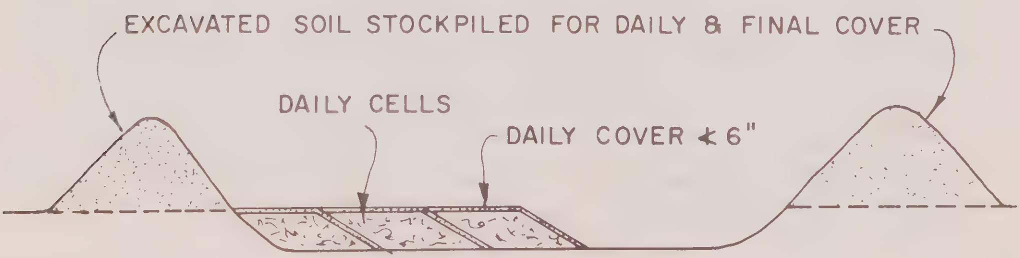
### ① USE OF EXISTING DEPRESSION CROSS-SECTION




*NOTE: ABSENCE OF SOIL OR USE OF MULTI CELL DEPTHS OFTEN REQUIRES PURCHASE OF COVER SOIL.*

### ② USE OF OPEN LAND

(a) *OPERATING SITE* CROSS-SECTION




(b) *COMPLETED SITE* CROSS-SECTION

4. It will be assumed that cost of the land, exclusive of buildings, fences and roads will be $1000/acre. (This is a reasonable figure for small communities in Ontario but in urban areas the cost could be more.)
5. Sufficient land will be purchased for a twenty year period at the start of the landfill operation.
6. It will be presumed that the landfill site will be used as a community recreation area and that it will not have a final resale value.

Table 3.1 provides the area of land required for a 20 year operation and the quantity of soil cover required per ton of waste for different cell depths and degrees of compaction. It is based upon the operation of one cell per day equivalent to a disposal rate of 25,000 tons/year. Since smaller cells will be needed for lower disposal rates and two or more cells might be operated simultaneously at higher rates, the table can only be used as a guide to land and soil usage.

The usual degree of compaction obtained in a well operated landfill site provides a density of between 700 to 800 lbs/cubic yard, equivalent to 26 to 30 lbs per cubic foot. For convenience in using the table and to arrive at the most favourable estimate for a landfill operation a figure of 30 lbs per cubic foot will be used. The use of multiple cell depths may be seen to provide a greater finished depth which effects a considerable conservation in land use. Although, this warrants special attention in the detailed design of the landfill site, simple cell operation with a finished rise of 10.5 ft has been assumed. This is in accordance with common practice.

## COST OF A LANDFILL OPERATION

The requirements for the development of the site are well established but the cost of meeting these will greatly depend upon the specific site which is chosen. Particular attention must be directed toward the proper drainage of the site during the landfill operation and at its completion. Boundary land, screens and fences will be needed to isolate the operation from the public view and to discourage

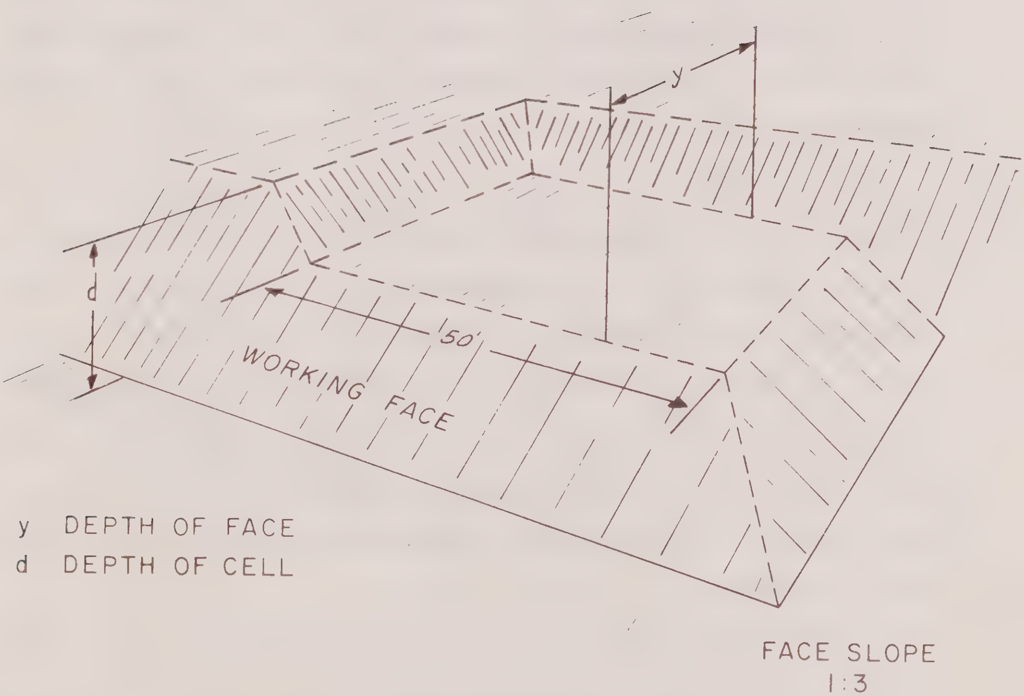



FIGURE 3.2 METHOD OF CELL DEVELOPMENT

illicit salvaging operations. Adequate roads, employee facilities, weigh scales and an equipment service centre should also be allowed for if the operation is to be conducted properly. A guide to the most satisfactory conditions is provided by the tentative 'Engineering Standards' developed by the Waste Management Branch (see Appendix A).

For small operations it will be presumed that an ideal site has been chosen which is close to an existing road and that only minimal site development is needed. For an operation handling less than 25,000 tons/yr, one crawler type tractor is probably all that is required for spreading, compaction of the waste and covering the fill with compacted soil. A front loader or tractor scraper or dragline will be needed to supplement this unit for a larger operation up to 50,000 tons/yr, or where the site conditions demand special operations. A suitable crawler tractor would cost approximately $25,000.

For landfill operations below 25,000 tons/yr a minimum of two men would be required, if only for reasons of safety. In this case the machine operator should also undertake the supervisory duties and to reduce the cost of the operation it could be undertaken on a part-time basis, thus releasing the men for other community work. At an operating level of 25,000 tons/yr the minimum work force would consist of a foreman, a tractor operator and a laborer. For an operating level of 50,000 tons/yr this labour force should be increased by one person and a further tractor operator will be needed at the 100,000 tons/yr level of operation. These requirements are in accordance with existing practice.

If the operation is to be well managed the wage rates should be set at levels which will attract and retain good operating labour. The labour cost has therefore been estimated on the basis of $3.50/hr for general labour, $5.00/hr for machine operators and $6.00/hr for supervisors. An overhead charge of 40 % on these rates has been included to allow for indirect costs of supervision, clerical staff and employee benefits.

Other operating costs for a landfill operation include such items as maintenance of equipment, rental of equipment, landscaping and road maintenance, heat, light, water and telephone, maintenance

TABLE 3.1: LAND AREA AND COVER SOIL REQUIREMENTS FOR 25,000 TONS/YEAR SANITARY LANDFILL OPERATION

| Cell Depth ft | Finished Rise ft | COMPACTION DENSITY lb/ft³ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 20 | | 30 | | 40 | | 50 | | 60 | | 70 | |
| | | A | V | A | V | A | V | A | V | A | V | A | V |
| 2 | 4.5 | 572 | 4.92 | 404 | 3.35 | 286 | 2.54 | 230 | 2.05 | 190 | 1.73 | 164 | 1.48 |
| | 7.0 | 288 | 2.98 | 192 | 2.14 | 144 | 1.63 | 115 | 1.33 | 96 | 1.12 | 82 | .98 |
| | 9.5 | 192 | 2.66 | 128 | 1.75 | 96 | 1.34 | 77 | 1.10 | 64 | .94 | 55 | .82 |
| | 12.0 | 144 | 2.27 | 96 | 1.57 | 72 | 1.21 | 57 | 1.00 | 48 | .85 | 41 | .71 |
| | 14.5 | 115 | 2.12 | 77 | 1.47 | 57 | 1.15 | 46 | .93 | 38 | .80 | 33 | .70 |
| | 17.0 | 96 | 2.00 | 64 | 1.40 | 48 | 1.08 | 38 | .90 | 32 | .78 | 27 | .68 |
| 4 | 6.5 | 286 | 2.70 | 190 | 1.87 | 143 | 1.44 | 126 | 1.26 | 90 | 1.00 | 82 | .88 |
| | 11.0 | 151 | 1.78 | 96 | 1.29 | 71 | 1.00 | 64 | .88 | 48 | .73 | 39 | .65 |
| | 15.5 | 96 | 1.57 | 64 | 1.12 | 48 | .88 | 42 | .78 | 32 | .66 | 27 | .59 |
| | 20.0 | 72 | 1.45 | 48 | 1.04 | 36 | .84 | 32 | .76 | 24 | .62 | 20 | .56 |
| 6 | 8.5 | 187 | 1.98 | 128 | 1.42 | 96 | 1.11 | 76 | .96 | 64 | .81 | 54 | .72 |
| | 15.0 | 96 | 1.44 | 64 | 1.07 | 48 | .85 | 38 | .73 | 32 | .65 | 27 | .58 |
| | 21.5 | 63 | 1.30 | 43 | .97 | 32 | .79 | 26 | .68 | 21 | .61 | 18 | .54 |
| 8 | 10.5 | 143 | 1.68 | 95 | 1.22 | 71 | .98 | 57 | .85 | 48 | .74 | 41 | .68 |
| | 19.0 | 71 | 1.30 | 48 | .97 | 36 | .81 | 29 | .70 | 24 | .63 | 20 | .58 |
| | 27.5 | 48 | 1.24 | 32 | .92 | 23 | .75 | 19 | .68 | 16 | .62 | 14 | .57 |
| 10 | 12.5 | 115 | 1.52 | 76 | 1.14 | 57 | .94 | 46 | .81 | 38 | .72 | 33 | .66 |
| | 23.0 | 57 | 1.25 | 38 | .95 | 29 | .80 | 23 | .71 | 19 | .65 | 16 | .61 |

Key A: Area in acres to nearest acre for 20 year site.

V: Volume in cubic yds of cover soil per ton of waste solid.

of buildings and fences, fire protection and pest control. For the City of Kingston in 1969 these amounted to a total of approximately $11,000. This charge is difficult to estimate without considering individual cases and the variation with the size of the operation has had to be assumed.

The cost per ton of solid waste disposal can now be approximately estimated for the tonnage range between 5,000 and 100,000 tons/yr and the result is given in Table 3.2.

It should be noted that for comparison with other systems of disposal it has been assumed that the land necessary for twenty years has been purchased at the start of the landfill operation. In common with the estimates for other systems, no allowance has been made for increasing disposal rates.

## DISCUSSION

The costs presented in this section can only be used to illustrate general principles and to provide a comparison with the costs for other methods of waste treatment. The significant conclusions are as follows:

(a) Landfill Operations for Small Communities

The development and operation of a satisfactory landfill operation for a rural community of less than 10,000 persons will require an initial capital investment of $51 - 65,000 and will develop an operating charge, of between four to five dollars per ton. Although the selection of site would normally not be too difficult, communities of this size should consider the transport of refuse to shared disposal facilities, since the larger disposal operations provide lower costs and offer the advantages of better supervision and control.

(b) 'Domestic Waste' and 'Other Refuse'

Little distinction between these wastes has been made in the Ontario Regulations. Waste containing food materials and other putrescibles, as commonly found in domestic wastes, is offensive and particular care must be taken in its disposal. 'Other refuse', such

TABLE 3.2: APPROXIMATE OPERATING COSTS FOR SMALL LANDFILL OPERATIONS

| TONNAGE/YR | PERSONNEL | LAND COST FOR 20 YR $1000 | EQUIPMENT & SITE DEVELOP. $1000 | AMORT.[4] 1000 $/YR | SOIL COVER 1000 $/YR | LABOR 1000 $/YR | OTHER OPER. COSTS 1000 $/YR | TOTAL OPER. COST 1000 $/YR | COST $/TON |
|---|---|---|---|---|---|---|---|---|---|
| 5,000[1] | 2 | 19.0 | 32.0 | 5.7 | 6.1 | 9.35 | 5.0 | 26.15 | 5.23 |
| 10,000[2] | 2 | 38.0 | 37.0 | 8.35 | 12.2 | 14.0 | 5.0 | 39.55 | 3.96 |
| 15,000[3] | 2 | 57.0 | 39.0 | 10.6 | 18.3 | 18.7 | 7.5 | 55.10 | 3.68 |
| 25,000[3] | 3 | 95.0 | 73.0 | 18.7 | 30.5 | 32.6 | 11.0 | 92.80 | 3.70 |
| 50,000 | 4 | 190.0 | 98.0 | 32.0 | 61.0 | 55.5 | 14.0 | 162.50 | 3.25 |
| 100,000 | 5 | 380.0 | 100.0 | 53.5 | 122.0 | 64.2 | 16.0 | 255.70 | 2.56 |

[1]Part time operation; 2 days per week

[2]Part time operation; 3 days per week

[3]Part time operation; 4 days per week

[4]Amortization @ 9 1/4 percent over 20 years

as rubble from buildings, metal objects, wood, clean waste paper products, and some inert industrial wastes, could constitute as much as 50 - 60 percent of the total waste in a community. This material might be treated separately and means devised for its use as clean fill, to reduce the size of landfill project and consequently the charges for waste disposal.

(c) Compaction Density

A compaction density of 30 lb per cubic foot could be achieved if due care is taken in the construction of the cells. This is the highest density that can be expected using standard compaction equipment, and under poor operating conditions the compaction density could be as low as 20 lb per cubic foot. The landfill costs which have been estimated are therefore conservative figures. Thus for 50,000 tons/yr with a cell depth of 8 ft and finished rise of 10.5 ft the cost of $3.25 per ton should be regarded as being the minimum charge.

The compaction of wastes to higher densities, although requiring special equipment, might be justified in some cases. For example, compaction to 60 lbs per cubic foot could be justified if the additional costs were less than $1.4 per ton since this situation is then equivalent to the operation of a landfill site of 25,000 tons/year capacity. Transportation to the site and conservation of the site would be important factors in this decision.

The effect of compaction on the degradation of putrescible material and the stabilisation of the site is unknown at the present time and further studies of this aspect would appear to be in order.

(d) Depth of Landfill

Although the detailed method of operation is dependent upon the nature of the site chosen, it is obvious that the construction of multi-layers of cells reduces the overall costs and greatly extends the life of the disposal site. For example, for the disposal of 50,000 tons/yr with a finished rise of 27.5 ft, the cost per ton is $2.60 as compared to $3.25 for a single cell depth. More significantly, the area required for the site is reduced to one-third that needed for single cell operation.

The construction of artificial hills is immediately suggested where the base is well prepared and sump drained and the waste is systematically compacted to form a hill of substantial height. From an economic and engineering viewpoint this solution is ideal but would probably find little public acceptance since the operations would be visible for many miles and many years would pass before the aesthetics or recreational aspects were recognised.

(e) The Problems

Although a sanitary landfill operation appears to provide a simple, inexpensive and satisfactory method of disposal, the inherent problems are:

(i) Location: The difficulty of finding a site which satisfies the criteria of technical suitability, economic feasability and public acceptance is becoming more difficult especially in urban areas.

(ii) Operation: Although regulations and procedures can be established for satisfactory operation, the actual operation will fail to meet these standards in Canada during many periods of the year. Frozen ground, snow and mud present many real practical difficulties to the operators.

(iii) Pollution: Fires and serious water pollution hazards should be a matter of history with the introduction of the new legislation, but the long term effects of the decomposition products of the waste are not known.

(iv) Lost values: Once the waste is buried, many valuable constituents can no longer be recovered. Landfill is a means of disposal and does not permit the recovery and recycling of materials.

# CHAPTER 4

## THE PULVERIZATION OF WASTE AND OPERATION OF LANDFILLS WITH PULVERIZED WASTE

The disintegration of refuse into relatively small particles has been practiced in Europe for many years as a prelude to the manufacture of compost, or landfill disposal. There are now a number of installations in North America of a similar type.

The milling or pulverization of refuse is not in itself a means of disposal but the benefits of this treatment prior to disposal by a landfill operation have caused several communities to install the necessary equipment or seriously consider its possibilities. In Canada, pulverizers for this purpose were operated by Sanitary Refuse Collectors Inc. of Montreal and are now being used by the City of St. Catharines.

On this continent, the City of Madison, Wisconsin, has been most active in exploring the possibilities of this treatment. It was assisted in this endeavour by a grant from the Department of Health, Education and Welfare and by the cooperation of the Heil Co. and the University of Wisconsin.

J.J. Rheinhardt[1], of the City of Madison, lists the following benefits which are to be obtained from pulverization prior to landfill disposal:

"1. Experience in the demonstration project has shown that milling refuse changes the characteristics of refuse in such a manner that cover material is not needed on the refuse immediately. It is felt an operation can be satisfactorily run by covering only when final grades are reached.

2. The milled material compacts more readily than the unmilled material and with no intermediate cover occupies less volume in landfill than unmilled refuse.

1. Rheinhardt, J.J. "A Report on Milled Refuse and the Use of Milled Refuse in Landfill", Presented to Dept. of Natural Resources, May 31, 1969.

3. The milled refuse presents a very minor paper blowing problem.
4. Milled refuse supports traffic operators during wet weather.
5. Milling refuse prevents hot ashes from reaching the fill area.
6. Cold and wet weather problems with covering operations found in regular landfill operations are eliminated.
7. The milled refuse has little or no odor.
8. The milled refuse, with proper management, does not readily support insects or rodents."

These claims are endorsed by other operators of similar equipment and are supported in the review by Childs of the Waste Management Branch[1].

THE PULVERIZATION OPERATION

Refuse from the collection trucks is off loaded and conveyed to the pulverizer, which is generally of the swing hammer type. The crushed material is then transported to the dumping site and is spread and compacted using a bulldozer.

To provide for a uniform flow of material to the pulverizer, the feeding arrangement must allow for a hopper or concrete pad so that collection vehicles can be discharged immediately upon their arrival. The conveyer to the pulverizer is then fed using a wide width conveyer or front end loader. Some salvaging of material and removal of any large uncrushable items is sometimes accomplished on this conveyer, but the larger pulverization units will either reduce these items or automatically reject them.

A suitable pulverizer of the hammer mill type will require approximately 15 to 25 HP per ton of waste pulverized per hour. There are at least five manufacturers of this type of machine which have operational experience with the pulverization of refuse. All the makes require daily maintenance to repair the wear on the hammer tips.

The discharge from the pulverizer is fed directly into trucks or into a small storage hopper to await transport to the landfill site.

1. Childs, K.A. Report to Ontario Dept. of Energy and Resources November, 1969.

COST OF PULVERIZATION

It is informative to attempt to calculate the cost of the pulverization process for a range of capacities.

For capacities at or below 10,000 tons/year it will be assumed that the refuse will be discharged from collection vehicle on to a concrete pad and that a front end loader will be used to feed the pulverizer conveyer. This arrangement will minimize the cost of equipment since the front end loader can be employed for other purposes in a part-time operation and some control on the materials fed to the pulverizer can be exerted by the operator. For capacities of 25,000 tons/year and above, it will be presumed that a 'live bottom' hopper will be employed to feed the conveyer to the pulverizer. The length of this hopper will be dependent upon the capacity required and the schedule envisaged for the collection vehicles.

A simple pulverizer unit will be considered to be adequate for plant capacities up to 25,000 tons/year. Above this figure, up to a capacity of 100,000 tons/year at least two pulverizer units will be presumed to be required. This will provide for at least partial coverage for maintenance or for a major breakdown of one of the larger units. For the small plants and for pulverizers used in conjunction with a landfill operation this aspect is not of critical importance since the normal landfill process could be employed if a serious malfunction occurred.

In all cases it will be presumed that the pulverizer unit and conveyer systems will be enclosed in a simple prefabricated building. If the units are to be used in conjunction with a landfill operation or are employed as transfer station equipment, trucks will be required for the transport of the pulverized product. These have not been allowed for in the estimate.

The approximate costs have been calculated and are presented in Table 4.1. Recently reported costs for pulverization range from \$2.10 to \$2.80 per ton for capacities in the range of 25,000 to 100,000 tons per year, and a mean value of \$2.60/ton was chosen to evaluate pulverization costs for other operations considered in the SERL report. The figures reported in Table 4.1 would therefore appear

TABLE 4.1: CAPITAL AND OPERATING COSTS FOR PULVERIZATION OF RAW MUNICIPAL WASTE

| ITEM | CAPACITY 1000 Tons/Yr | | | | | |
|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 25 | 50 | 100 |
| **1. Operating Data** | | | | | | |
| Days Oper/Wk | 2 | 3 | 4 | 4 | 5 | 5 |
| Tons/Op/Day | 48 | 64 | 72 | 120 | 192 | 384 |
| Tons/Hr | 6 | 8 | 9 | 15 | 24 | 48 |
| No. of Pulverizers | 1 | 1 | 1 | 1 | 2 | 4 |
| No. of Operators | 2 | 2 | 2 | 3 | 4 | 4 |
| Power (Inst'd H.P.) | 200 | 200 | 200 | 400 | 800 | 1600 |
| **2. Capital Cost: $1000** | | | | | | |
| Pulverizers (Inst'd) | 54 | 54 | 54 | 75 | 150 | 300 |
| Conveyer, Hoppers (Inst'd) | 15 | 15 | 20 | 60 | 75 | 105 |
| Building & Site | 10 | 10 | 10 | 20 | 25 | 40 |
| Front End Loader | 10 | 15 | 20 | - | - | - |
| Total Capital Cost | 89 | 94 | 104 | 155 | 250 | 445 |
| **3. Operating Costs $1000/yr** | | | | | | |
| Laborers | - | - | - | 7.3 | 14.6 | 14.6 |
| Operators | 20.8 | 20.8 | 20.8 | 20.8 | 20.8 | 20.8 |
| Overheads @ 40 % | 8.4 | 8.4 | 8.4 | 11.2 | 14.2 | 14.2 |
| Total Labour | 29.2 | 29.2 | 29.2 | 39.3 | 49.6 | 49.6 |
| Maintenance @ 10 % | 8.9 | 9.4 | 10.4 | 15.5 | 25.0 | 44.5 |
| Power & Services | 1.5 | 3.0 | 4.3 | 7.7 | 19.0 | 35.0 |
| Amortization | 9.9 | 10.4 | 11.5 | 17.2 | 28.0 | 49.7 |
| Total Op. Cost | 49.5 | 52.0 | 55.4 | 79.7 | 121.6 | 178.8 |
| **4. Unit Costs** | | | | | | |
| Cap Cost/Ton Day $ | 1,850 | 1,470 | 1,440 | 1,290 | 1,300 | 1,170 |
| Op. Cost/Ton $ | 9.90 | 5.20 | 3.70 | 3.20 | 2.43 | 1.78 |

to provide a reasonable first estimate of the costs for pulverization.

Some reduction of these costs might be achieved by shift operation as indicated by the Wisconsin report, but this would only change the costs for large operations by a fractional amount. No change could be expected in the figures for operations with a capacity below 25,000 tons per year since it was assumed that these would be operated on a part-time basis and shift work would not be warranted. The costs of operation of the smaller pulverization operations might be reduced, however, by modifying the specifications for the product or material to be pulverized and thereby allowing the use of simpler and less expensive equipment.

It should also be noted that the costs are based on the pulverization of the total quantity of waste stated in the tables. Although the larger pulverizers will handle large items or automatically reject them no allowance has been made for the separation and handling of these items. It was presumed that these costs would be approximately equivalent to the cost of their pulverization on a weight basis.

## THE OVERALL COST OF A COMBINED PULVERIZATION AND LANDFILL OPERATION

Many communities in Ontario are actively considering the alternatives to a dump or simple landfill operation. The advantages of pulverization as a prior treatment to disposal by a landfill operation are visually obvious and are of particular value in maintaining satisfactory landfill conditions during the Canadian winter. It is of value to consider therefore the operating costs for this combined operation to indicate the economic limitations of this method of disposal.

Although it is generally agreed that pulverization of the waste produces a material which is more readily handled and compacted, there is little operating information on the compacted density which can be achieved or will finally result, for North American conditions. Preliminary data obtained by the University of Wisconsin, for the Madison project, has been reported by Childs and is reproduced in Table 4.2.

TABLE 4.2: UNIVERSITY OF WISCONSIN COMPACTION DATA

| ITEM | Pulverized Refuse Weight Range | | | Normal Refuse Weight Range | | |
|---|---|---|---|---|---|---|
| | High | Low | Av. | High | Low | Av. |
| Density lb/cu.yd. | 1130 | 760 | 953 | 590 | 440 | 540 |
| Density lb/cu.ft. | 41.5 | 28.2 | 35.3 | 22. | 16.3 | 20.0 |
| Compaction Time hrs/100T | 4.0 | 3.9 | 3.9 | 9.8 | 12.2 | 9.2 |
| Settlement Time wks. | 8 | 8 | - | 19 | 5 | - |
| Season Cell Construction | Summer | Winter | - | Spring | Winter | - |

Proponents for pulverization of refuse prior to a landfill operation have suggested that a bulk reduction of over 100 percent can be accomplished[1] The Wisconsin average data indicates that a reduction of approximately 45 percent in volume is more reasonable and it is presumed that figures of the order of 100 percent refer to a volume reduction based on refuse volume as collected. Further support for this lower volume reduction is the figure of 33.0 percent reduction obtained in the Montreal operation[2].

The Wisconsin figures for the density of compacted normal refuse in a landfill operation are lower than might be expected for a well operated operation in Canada. A figure of 26 lb/cu.ft. (700 lb/cu.yd.) is a commonly used in estimating the capacity of landfill sites. The Wisconsin report records an average of only 20 lb/cu.ft. (540 lb/cu.yd.) was obtained. It will be recalled that a figure of 30 lb/cu.ft. (810 lb/cu.yd.) was used to provide a conservative cost for a landfill operation in the previous section of this report.

For the purpose of estimating the cost of disposal of pulverized material it will be assumed that a 33.0 percent reduction in volume can be achieved in comparison to compacted landfill of 30 lb/cu.ft. density. This provides a working figure of 45 lbs/cu.ft. which is 10 percent higher than the maximum achieved during the preliminary tests at Wisconsin.

1. In Convention used, percentage reduction is based on percent of final volume.
2. J. Johnson, Engineering Journal June 1969.

Compaction data for Canadian conditions is urgently required if the economic advantages of pulverization are to be properly assessed. It is believed, however, that the assumptions made with respect to compaction will provide a reasonable first estimate of the operating costs. The complete cost analysis for a combined pulverization landfill operations for the disposal of between 5,000 and 100,000 tons/year of waste is given in Table 4.3. The analysis is based upon the following conditions.

1. Pulverization costs will be as previously reported in this Chapter.
2. By virtue of the properties of the pulverized refuse, daily cover soil will not be required.
3. Periodically the pulverized and compacted refuse fill will be covered with cover soil, 2 ft in depth, to finish the site to acceptable standards.

The unit costs for pulverization and landfill given in Table 4.3 are higher than those estimated by the University of Wisconsin (see Table 4.4). The difference might be ascribed to higher labour and equipment costs, higher interest rates and more conservative assumptions made in the present report.

A comparison of the operating costs for this combined operation with the corresponding values for the costs of pulverization and landfill as separate operations is given in Figure 4.1. It will be noted that pulverization, as a prior treatment of the refuse before disposal on a landfill site, increases the cost of disposal for all the operating capacities which have been investigated.

## DISCUSSION

The operation of a landfill disposal system is greatly assisted, particularly in Canada, by the prior pulverization of the waste material. On the other hand, the introduction of the pulverization operation significantly increases the costs for disposal for most communities in comparison with the cost of a normal landfill operation. This additional cost might be warranted in order to conserve existing landfill sites or to ensure that the Waste Management Regulations can

be effectively implemented throughout the year. In other instances the extra charge might be justified as a means of winning public acceptance for a landfill site location or might be considered to be reasonable on aesthetic grounds.

A more detailed analysis of the overall operation would appear to be urgently required. More information is needed on comparative compaction densities and settled volumes before precise cost estimates can be made. The conservation of a site by virtue of the higher compaction density achieved with pulverized material may not be as great as some proponents claim, especially if allowance is made for the final settlement which inevitably occurs. More data is also required on the degradation of waste fill and the quantity and properties of the leachate. Presumably the issue of standards for the operation of landfill sites with pulverized waste will need to await the outcome of this work.

In the meantime, some degree of caution should be exercised. Many of the benefits achieved by the prior pulverization of wastes can also be attained by the careful management of a sanitary landfill operation. Furthermore, material rejected by the pulverizer or presorted waste will need to be handled separately and although the costs of this operation have been partially allowed for in the estimates, the problems created by this waste stream should not be underestimated. It is also pertinent to note that whether the material is pulverized or not, the final result is the same; the waste materials are buried and their value is lost.

TABLE 4.3: APPROXIMATE COSTS FOR LANDFILL OPERATIONS WITH PRIOR PULVERIZATION OF THE WASTE

| ITEM | CAPACITY 1000 Tons/year | | | | | |
|---|---|---|---|---|---|---|
| | 5 | 10 | 15 | 25 | 50 | 100 |
| 1. Operating Data: | | | | | | |
| Days Op./Wk. | 2 | 3 | 4 | 4 | 5 | 5 |
| Tons/Op Day | 48 | 64 | 72 | 120 | 192 | 384 |
| Tons/Hr | 6 | 8 | 9 | 15 | 24 | 48 |
| Acres Land Usage/Yr | 0.64 | 1.27 | 1.91 | 3.18 | 6.35 | 12.7 |
| Soil Cover/Yr 1000 yds | 2.06 | 4.12 | 6.18 | 10.30 | 20.6 | 41.2 |
| No of Operators: | | | | | | |
| Landfill | 2 | 2 | 2 | 3 | 4 | 5 |
| Pulverization | 2 | 2 | 2 | 3 | 4 | 4 |
| Total | 4 | 4 | 4 | 6 | 8 | 9 |
| 2. Landfill Cap Costs $1000 | | | | | | |
| Land For 20 Years | 12.8 | 25.4 | 36.2 | 63.6 | 120.7 | 254 |
| Equipment & Site Dev. | 40.0 | 45.0 | 51.0 | 85.0 | 118.0 | 140 |
| Total | 52.8 | 70.4 | 87.2 | 148.6 | 238.7 | 394 |
| 3. Landfill Op Cost $1000/yr | | | | | | |
| Amortization | 5.9 | 7.8 | 9.7 | 16.7 | 26.7 | 44.0 |
| Soil Cover | 2.1 | 4.1 | 6.2 | 10.3 | 20.6 | 41.2 |
| Labor | 9.4 | 14.0 | 18.7 | 32.6 | 55.5 | 64.2 |
| Other Op Costs | 2.5 | 2.5 | 3.7 | 5.5 | 7.0 | 8.0 |
| Total Op. Cost | 19.9 | 28.4 | 38.3 | 65.1 | 109.8 | 157.4 |
| 4. Pulverization Costs | | | | | | |
| Capital $1000 | 89 | 94 | 104 | 155 | 250 | 445 |
| Operating $1000/yr | 49.5 | 52.0 | 55.4 | 79.7 | 121.6 | 178.8 |
| 5. Total Combined Costs | | | | | | |
| Capital $1000 | 141.8 | 164.4 | 191.2 | 303.6 | 488.7 | 839.0 |
| Operating $1000/yr | 69.4 | 80.4 | 93.7 | 144.8 | 231.4 | 336.2 |
| 6. Unit Costs | | | | | | |
| Capital Cost/Ton Day$ | 2,940 | 2,570 | 2,660 | 2,520 | 2,550 | 2,180 |
| Op. Cost/Ton $ | 13.90 | 8.04 | 6.25 | 5.80 | 4.62 | 3.36 |

TABLE 4.4: PROJECTED MILLING COSTS PER TON FOR MADISON, WISCONSIN.

| NUMBER OF MILLS | NUMBER OF SHIFTS | NUMBER OF TONS (daily) | COST PER TON |
|---|---|---|---|
| 1 | 1 | 56 | $5.15 |
| 4 | 1 | 224 | $2.79 |
| 1 | 2 | 112 | $4.01 |
| 4 | 2 | 448 | $2.15 |

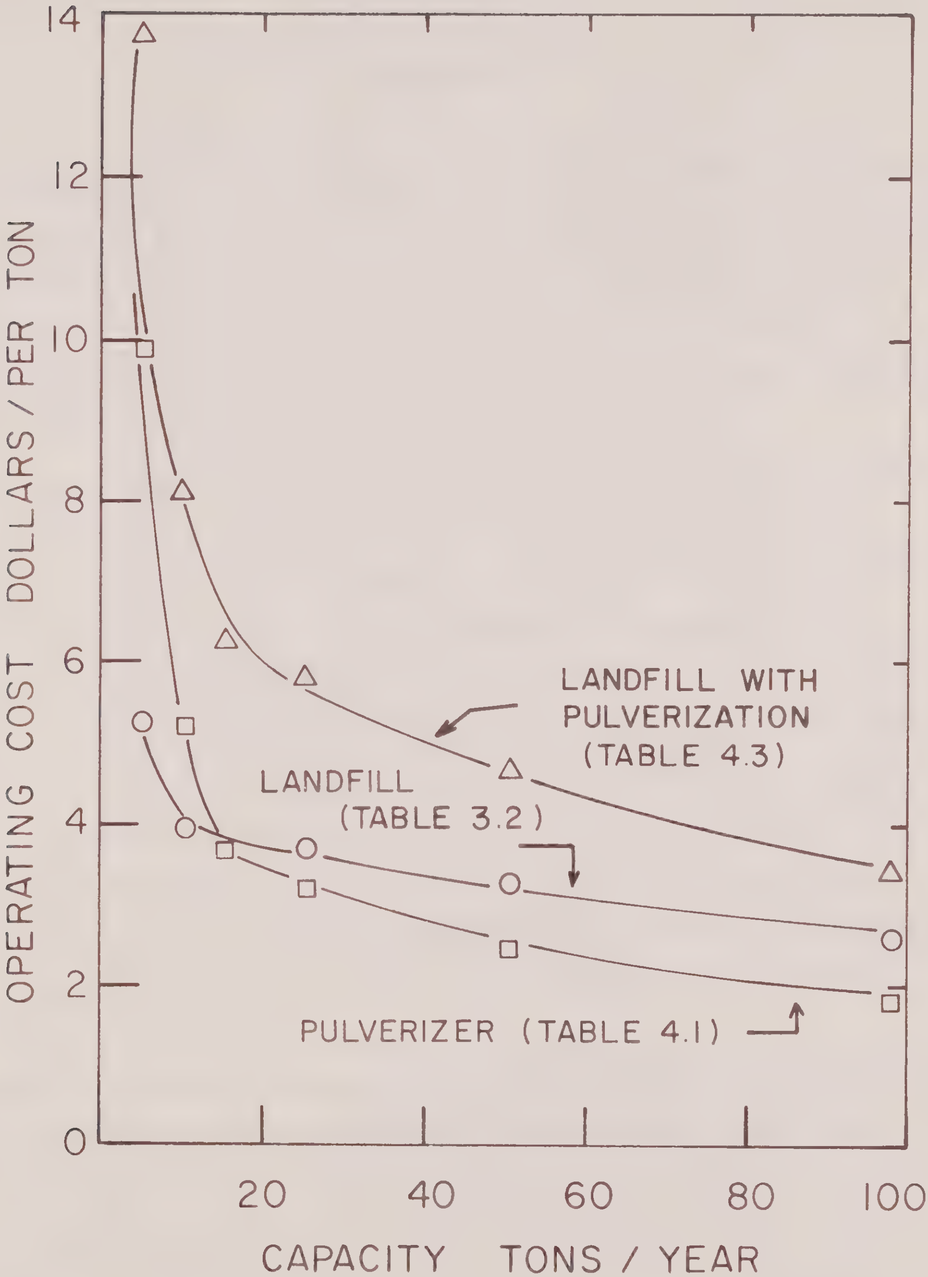



FIGURE 4.1: COSTS FOR LANDFILL, PULVERIZATION, AND LANDFILL WITH PULVERIZATION

# CHAPTER 5

## INCINERATION

The first incinerators for the disposal of domestic waste were built in England nearly a century ago. Since that time the process has been developed to the stage at which a modern plant can be designed to provide power and steam, recover metal scrap and satisfy the most recent air pollution codes. A variety of designs is available to provide capacities varying from those suitable for apartment buildings to those capable of handling 1200 tons per day of refuse.

The recent air pollution regulations in the U.S.A. and Canada have necessitated the inclusion of devices to remove particulate matter from emitted gases and this has increased the operating costs especially for the small incinerator. Fortunately the sulphur content of most wastes is low and equipment for the removal of sulphur dioxide or any other gases is not yet required[1].

There is a considerable amount of Canadian experience in this field. Incinerators have been employed by the larger cities for many years. For example, two 300 tons/day units were built in Montreal in 1930, followed by two 500 tons/day units in 1956. Many of these older units are now being replaced in the face of rising maintenance and operating costs and the need to reduce particle emission. In the case of the two units cited costs had risen to $10.00 and $5.50 per ton of refuse handled.

In contrast, Montreal has now installed, as a unit, four 300 ton/day incinerators, designed by Von Roll Ag, of Zurich which will provide steam generation and control the particle emission to below 0.17 lb/1000 lb gas. Of particular interest to Canadians is the novel approach taken by Gordon L. Sutin and Associates of Hamilton in the design of the new Hamilton solid waste reduction unit. This unit promises to reduce operation costs to $4.10 per ton at an operating level of 900 tons/day for a capital investment of $7,748,000 excluding

1. E.R. Kaiser, J. Air Poll. Control Association. 1968. 18 No. 3 p. 171.

income from sales of steam and recovered materials.

A well designed incinerator with heat recovery is as complex an engineering installation as a solid fuel power plant but in addition the designer must make allowance for the following factors[1]:

1. Variability of solid waste

   The variability of the feed material which can be short term, seasonal or even annual causes considerable difficulty In the older units, for example, problems are being experienced in attempting to maintain feed rates as the calorific value of the waste increases annually. Short term variations in feed quality, particularly in moisture content, are often compensated by the use of supplementary fuel but otherwise create severe control problems.

2. Slag

   Slag control necessitates the inclusion of special cooling systems.

3. Air pollution abatement

   This requires the installation of scrubbers or electrostatic precipitators which are subject to severe corrosion by the gases produced, particularly from some materials such as P.V.C.

4. Water

   Water is generally used in considerable quantities for cooling and quenching the ashes. To avoid a water pollution problem a waste water treatment plant is often required.

5. Ash and residue disposal

   Disposal of residues from the incinerator require quenching equipment and facilities for disposal. Since the residue quantity amounts to 10 to 50 percent of the refuse collected this can be a major concern.

6. Maintenance

   High maintenance costs have been experienced in tube repair of the boiler sections.

1. P.W. Kalika, J. Eng. for Power, April 1968, p. 205

7. Disruptions in service

   Provision must be made for suitable storage to allow for the irregularity of waste disposal collections and the results of law-enforced and planned shutdowns.

These factors complicate the design and operation of the unit which in turn is reflected in the capital and operating costs. A summary of operating data for existing and projected installations is given in Table 5.1. Like other manufacturing processes the charges increase with decreasing capacity.

Incineration on a large scale appears to satisfy many of the criteria for an ideal disposal system. Energy in the form of power or steam can be extracted, metals can be recovered from the ash, the operation can be conducted without significant pollution or health problems and the refuse can be reduced to a sterile waste which might be employed as a stable fill material. On the other hand, the high maintenance costs, the operation of pollution control equipment to meet higher standards, contractural problems with energy sales and the problems of residue handling have caused many engineers to question whether this disposal process can survive.

One problem which has not received as much attention as it deserves is the selection of the capacity of an incinerator unit and the cost of its expansion. The capacity of incinerators is now generally stated in terms of tonnage of refuse handled, but the process requires a rating in energy units on the same basis as used for the design and the operation of other power equipment. If this is done and allowance is made for the increasing calorific value and quantity of refuse, the result can be surprising. For example, the calorific value of the refuse has been increasing at a rate of 2 percent per year, and if it can be assumed that the quantity of refuse per person and the number of persons increases at a similar rate of 2 percent per annum then the annual increment in total energy production will be $(1.02)^3 - 1.0$ i.e., 6.12 percent per year. For these conditions, an incinerator unit to service a community for a ten year period should be designed for a capacity 93 percent in excess of present requirements or provision must be made for its expansion during the ten year period. Failure to

recognise this problem has led to the rapid obsolescence of equipment and severe operating problems.

The design and operation of small capacity incinerators must recognise many of these problems with the possible exception of those relating to power generation, since the high capital costs associated with power generation tends to make this a prohibitively expensive feature for small units. As previously mentioned, the scale factor also tends to make these units, even without power generation, too expensive to be considered for a small community. However, in view of the objectives of this study, a cost study appears to be warranted.

A review of the reported capital and operating costs for a number of existing and proposed incinerators is included in Table 5.1. No attempt was made to update these operating cost figures since in most cases insufficient operating data was given. The equivalent capital costs at 1970 prices have been estimated, however, using the ENR index and the unit capital cost per ton day has been related to annual tonnage in Figure 5.1.

This data can only be used as a guide to determine the approximate capital and operating costs in view of the many design variables and diverse operating conditions. It would appear that sophisticated incineration equipment cannot be justified for the smaller communities where the amount of waste is less than 50,000 tons/year unless the air pollution standards are relaxed for these communities or a new type of low capacity incinerator is devised. In this connection some new designs with after-burners to reduce smoke emission would appear to be worthy of future consideration for this low tonnage range of operation.

To establish an operating figure for incineration, comparable with those developed for other processes considered in this report, a detailed cost estimate for incineration of 50,000 tons/year was undertaken.

TABLE 5.1: SUMMARY OF INCINERATION OPERATING DATA

| LOCATION | DATE | CAPACITY 1000 T/Yr | CAPACITY Ton/ Op.Dy | CAPITAL COST MILLION $ Report -ed | CAPITAL COST MILLION $ 1970 Est. | 1970 Unit Cost $/Ton Op.Dy | Oper. Cost $/Ton | REMARKS |
|---|---|---|---|---|---|---|---|---|
| Hamilton[1] (Proposal) | 1969 | 100 | 300 | 4.69 | 4.83 | 16,100 | 8.75 | Waste segregated, pulverized and incinerated with thermal recovery and salvage of metal. Operating cost includes amortization at 7 % over 20 years but excludes sales of steam and metal. |
| | | 200 | 600 | 6.25 | 6.45 | 10,700 | 5.32 | |
| | | 300 | 900 | 7.75 | 8.00 | 8,900 | 4.10 | |
| | | 500 | 1500 | 12.5 | 12.9 | 8,600 | 4.56 | |
| Montreal[2] (Proposal) | 1969 | 400 | 1200 | 8.5 | 9.0 | 8,350 | 4.00? | Thermal recovery only. Operating cost includes amortization at 9 % over 20 years, but excludes sales of steam. |
| U.S.A.[3] (Estimates) | 1968 | 44 | 170 | 1.75 | 2.00 | 11,900 | 7.80 | No recovery of energy or materials. All units operated 5 day per week, with the two lowest sizes operated on 2 shift basis. Operating charges reestimated at amortization of 9 % over 20 years. |
| | | 140 | 400 | 3.30 | 3.75 | 9,100 | 3.80 | |
| | | 218 | 840 | 4.80 | 5.5 | 6,550 | 3.36 | |
| | | 312 | 1200 | 6.10 | 6.95 | 5,800 | 2.86 | |
| U.S.A.[3] (Estimate) | 1968 | 44 | 170 | 2.00 | 2.30 | 13,500 | 8.55 | Thermal recovery only. Operating charge includes amortization, excludes steam sales. |
| New York[4] | 1966 | 240 | 1000 | 8.00 | 10.30 | 10,300 | - | Minimal Equipment. No energy recovery. |
| Canada (This Report) | 1970 | 50 | 138 | 1.22 | 1.22 | 8,850 | 8.28 | See estimate given in Chapter 5. 24 hr day operation. |
| England[5] | 1969 | 48 | 132 | 1.38 | 1.45 | 10,900 | 7.56 | 16 hr day operation. Metal recovery only. |
| Germany[4] | 1966 | 800 | 2380 | 21.7 | 28.2 | 11,800 | - | Residue & Metal Salvage, Electrical Power Generation |
| Austria[4] | 1966 | 200 | 600 | 9.6 | 12.4 | 20,800 | - | |
| Holland[4] | 1966 | 400 | 1540 | 9.25 | 12.0 | 7,800 | 2.50* | |
| France[4] | 1966 | 600 | 1800 | 20.0 | 26.0 | 14,500 | - | |

*net 1966

1. Sutin C.L. Solid Waste Reduction Unit. Public Works. Feb. 1969.
2. Annon: Montreal Incinerator Eng. News Record. p. 62 Aug. 1969.
3. Heaney, F.L. Regional Districts for Incineration Civil Eng. A.S.C.E. p. 69 Aug. 1968.
4. Rogus, C.A. European Developments in Refuse Incineration Public Works May 1966.
5. Thompson, A.W. Proposed refuse incineration plant, Exeter J. Inst. Municipal Engrs. 69 p. 108. 1969.

COST OF INCINERATION FOR 50,000 TONS PER YEAR OF WASTE

The design and operation of an incinerator must comply with the regulations[1] made under the Air Pollution Control Act 1967 and the amendments (Statutes of Ontario 1967 C2, 1968 C3, and 1969 C2). It will be presumed, therefore, that dust removal equipment must be installed.

An incinerator of 50,000 tons/year is of intermediate size between the small-batch incinerators and the larger continuous incinerators now in operation. The addition of steam generation equipment would not appear to be justified and it will be assumed that the simplest devices will be used for materials handling and control. To allow for temporary overloads and control the unit will be designed with a 10 percent overload factor.

The following data will be assumed:

| | | | |
|---|---|---|---|
| Operating Schedule: | Continuous, 8760 hrs/yr | | |
| Quantity of Waste: | 50,000 tons/yr | | |
| Composition of Waste: | Ash Generation: | 20 percent | |
| | Water Content: | 20 percent | |
| | Calorific Value: (as fired) | 4,800 Btu/lb | |

An approximate estimate for the equipment required for these conditions was made and is as follows:

| | |
|---|---|
| Building and Site Development | $ 400,000 |
| Incinerator Unit | 160,000 |
| Loading Equipment | 40,000 |
| Fans, Scrubbers & Gas Cleaning | 95,000 |
| Stack | 87,000 |
| Ash Disposal System | 40,000 |
| Mechanical & Electrical Engineering | 200,000 |
| Land - 5 acres | 5,000 |
| TOTAL . . . . . . . . . . . . . . . . . . | $1,017,000 |
| Contingencies @ 20 % | 203,400 |
| Total Capital Cost | $1,220,400 |

1. Regulation 133/70 March 19, 1970

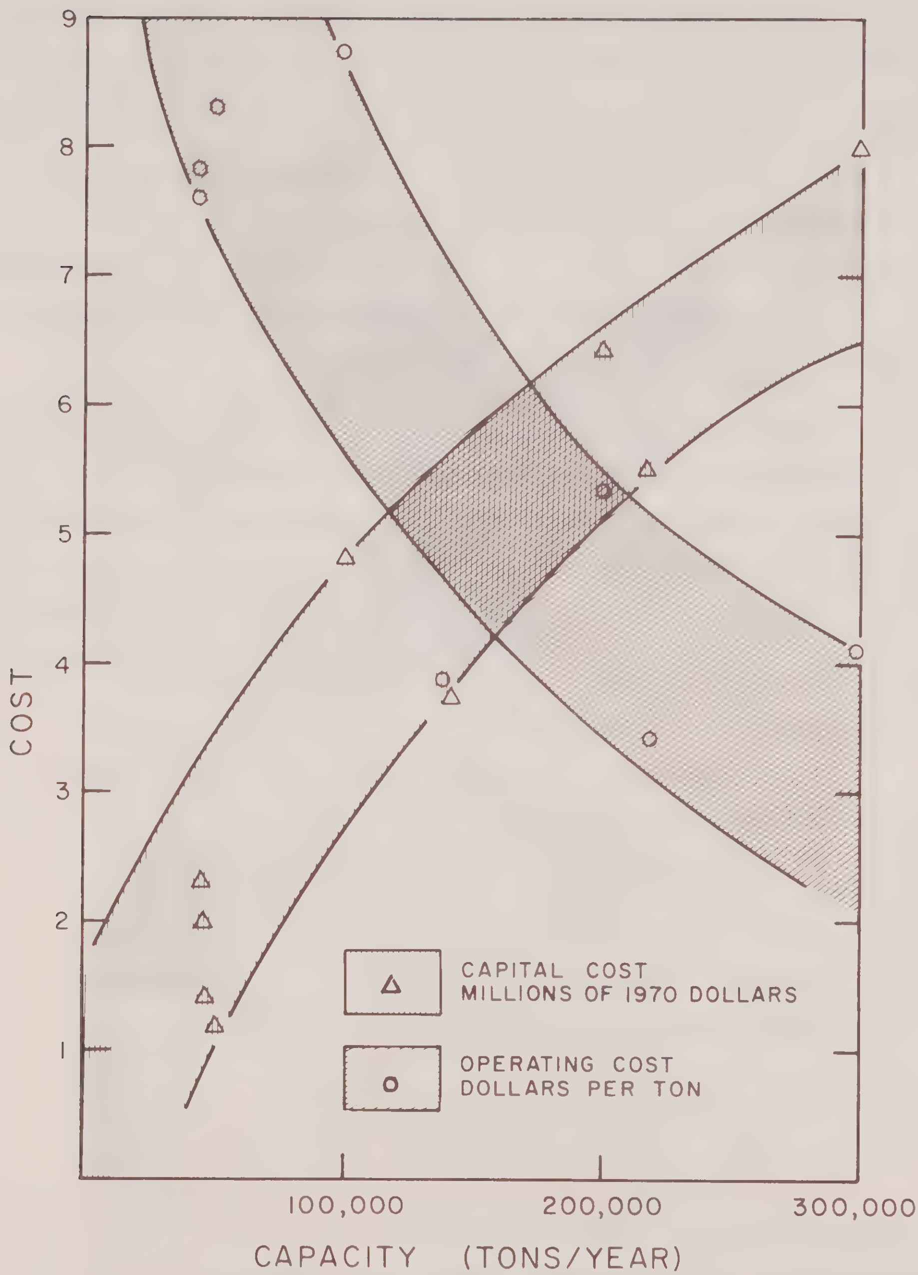



FIGURE 5.1: COST-CAPACITY RELATIONSHIPS FOR INCINERATORS (DATA FROM TABLE 5.1)

This has been calculated for 24 hours operation, 7 days per week, 52 weeks per year and no allowance has been made for prolonged shutdown or for the increase in refuse quantity and quality which will occur from year to year. This is therefore a very conservative estimate of the capital cost requirements.

The figure of $1,220,400, which provides a unit cost of $8,850 per ton operating day is similar to that expected from consideration of Table 5.1. It is concluded, therefore, that $1,220,400 may be taken as a reasonable first estimate for a unit of 50,000 tons/year capacity which is operated continuously.

Although the incinerator will be continuously operated it is assumed that the refuse will be collected and received during the day shift and that the refuse storage facilities are adequate for a three day operating period. It will also be assumed that maintenance of the plant will be subcontracted except for the routine maintenance which will be undertaken by the operating staff. Under these conditions a conservative estimate of the operating charges, excluding amortisation costs, will be as follows:

| | $/yr |
|---|---|
| Labour: | |
| Plant Supervisor @ $6.00/hr | 12,500 |
| Operators - 4 @ $5.00/hr | 41,600 |
| Stokers & Ash Handlers-8 @ $3.50/hr | 58,400 |
| Scaleman-1 @ $3.50/hr | 7,300 |
| Total Direct Labour Costs | 119,800 |
| Overheads @ 40 % | 47,600 |
| Total Labour Costs per year | 167,400 |
| Maintenance and Supplies: | |
| Maintenance @ 5 % of fixed costs | 61,200 |
| Utilities | 30,000 |
| Total Maintenance and Supplies | 91,200 |
| Residue Disposal Costs @ $1 per ton | 16,500 |
| (Based on 30 % residue and unacceptable material) | |
| Total Operating Charge | $274,700 |

It may be concluded that, as a conservative estimate, the capital charges for the incineration of 50,000 tons/yr will be approximately 1.25 million dollars and the operating cost, excluding amortisation charges, will be $5.50 per ton. With amortisation included at 9 1/2 percent over a 20 year period, this figure would be increased to $8.28 per ton.

DISCUSSION

The significant conclusions are as follows:

1. The operating cost of $8.28 per ton to handle 50,000 tons per year is a conservative estimate and if air pollution standards similar to those for large scale units are to be observed, a suitable unit for a small community (ca 50,000 persons) is likely to be prohibitively expensive.
2. It is doubtful whether the existing large scale units can be considered to be satisfactory, in view of the many technical problems associated with incineration and the relative inflexibility of units to provide for more stringent air pollution standards and for the continuously increasing requirement for thermal capacity.
3. Incineration is not an ideal disposal system. On a dry basis, up to 50 percent, with an average of approximately 25 percent, of the refuse collected cannot be burned or appears as residue. Although much of this material will not create a severe health or pollution hazard it must be disposed of by other means. In the estimate for a 50,000 ton/yr operation the disposal cost was assumed to be only one dollar per ton, but in some locations transportation and landfill operations could easily increase this figure and could approach that for a landfill operation.
4. As a reclamation system, the larger units recover energy and some metals from the residue. Paper, one of the most valuable elements of refuse, is destroyed and the reclamation of other materials, with the exception of ferrous metals, is more difficult or impossible to achieve.

5. The virtue of operating a large incinerator unit on a regional basis is clearly indicated by Figure 5.1. Furthermore, at the higher capacities, identical incinerator units can be installed to provide some margin for downtime and fluctuations in the feed rate. From Figure 5.1 it appears that for the purposes of this report, the operating cost would be approximately $7.50 per ton at a rate of 100,000 tons per year; from extrapolation of the data, below 50,000 tons/year is not justified, although it is obvious that the operating costs rapidly increase.

# CHAPTER 6

## COMPOSTING

Before the twentieth century much of the biodegradable waste material was returned to the land directly or as compost to maintain the fertility of the soil. Artificial fertilizers have now been widely accepted as an 'efficient' method of supplying concentrated nutrients to provide greater yields per acre. As a result, natural organic materials only account for approximately 2.0 percent of the fertilizer market and in the U.S.A. compost sales on a tonnage basis are barely significant at 0.1 % of the total fertilizer consumption. On the other hand many authors, particularly those writing for gardening magazines, become almost lyrical in extolling the virtues of compost as a soil conditioner. Their enthusiasm is supported by many technical articles on the influence of compost on plant growth which emphasise that composts should not be compared with fertilizers since they serve different soil requirements, and tend to complement each other.

Waksman[1] summarised the benefits of compost addition to the soil as follows:

"1. It serves as a storehouse of plant nutrients; the gradual decomposition of the organic matter by micro organisms results in the liberation of a continuous stream of $CO_2$; of available $N_2$ as ammonia; of phosphorus and of other elements essential for plant growth.

2. It has important physical effects upon the soil; it improves the soil structure; it provides better aeration; it has a binding effect upon the soil particles; it increases the water holding capacity of the soil; it helps the soil to absorb more heat; it increases the buffering properties of the soil preventing rapid changes in acidity and alkalinity.

1. Waksman, S.A. "Humus" Baillerie, Tindall and Cox, 2nd Ed. (1938).

3. It has certain chemical effects upon soil constituents rendering various elements such as phosphorous, more soluble, and neutralising substances which tend to be toxic to plants; it has a high base holding power and it enhances the utilisation of mineral fertilisers by plants.
4. It has a mechanical effect upon the soil, providing a more favourable medium for the development of the root system of plants and for the growth of micro organisms essential for soil processes.
5. By favoring the growth of the common saprophytic bacteria, fungi, protozoa and neonatodes it has an antagonistic effect upon micro organisms to plants."

This summary was made by Waksman in 1938. A very similar summary of the benefits was made by E.D. Kane[1] in 1967, concerning the utility of compost made from municipal wastes. This potential attractiveness of converting waste into a valuable soil conditioner has engaged the attention of many engineers and entrepreneurs and several processes have been developed. Nevertheless, little has been accomplished in the U.S.A. or Canada for the following reasons:

1. Quality

   Compost made from municipal waste is of variable quality and many processes have not provided a marketable product in terms of handling and spreading characteristics and freedom from harmful or unsightly materials such as as large glass fragments, scrap metals and plastic objects.
2. Economics

   The failure of many composting operations in the U.S.A. can be seen to arise from overly optimistic estimates of the profitability of the operation and the market potential[2].
3. Educational, Political and Social Problems

   The poor performance or failure of many early units has discouraged the development of new plants and public acceptance of compost product. Furthermore, in spite of reassurance

1. Kane, E.D. Technical-Economic Study of Solid Waste Disposal Needs and practices H.E.W. report SW-TC: Compositing.
2. Kolb, L.P. Compost Science 8, 2, 1968.

the public has been slow to accept the siting of compost units in urban centres.

4. Transportation Costs

For economic reasons, compost plants can only be sited in the larger communities for which, in the U.S.A., there is often no immediate market for the product. The compost product must therefore be transported in competition with other soil conditioners to the rural areas.

In Canada, composting has never been attempted on a large scale and it is possible that the public and communities will accept this process more readily than in the U.S.A. at the present time. It is also possible that some of the specific uses of compost, for example in reforestration or stabilization of land[1], will be found to have greater appeal.

## COMPOSTING PROCESSES

Composting is the common name given to the bacterial fermentation of organic materials of a cellulosic nature in the presence of oxygen. The process can be accomplished in many ways but all involve at least partial sorting to segregate compostable material, the intimate mixing of this material and control of the aeration, moisture and temperature of the fermenting material.

It was the need for compost in the smaller heavily populated countries that inspired the development of composting processes to utilize municipal waste. Descriptions of these processes are now of historical interest but they might be reviewed in a future study to provide the starting point for the design of low cost small capacity composting units for rural communities. Notable among these early developments was the example of the Netherlands Government in the sponsorship of a refuse disposal company (V.A.M.) in 1929, which has led to the conversion of nearly 30 percent of the city wastes to compost in that country[2].

1. Special Report 2nd I.R.G.R. Congress Compost Science, Summer 1962.
2. Teensma, B. Compost Science 1, 4, 1961

The emphasis has now changed. Composting is now being considered as a method of disposal of municipal waste whereas the need for compost, if measured in terms of agricultural acceptance, is almost non-existent in North America. It is possible that a demand for municipal compost can be developed, but even if this is not possible composting merits serious attention as a means of "sanitizing" municipal waste and of combining sewage disposal with garbage disposal in one unit.

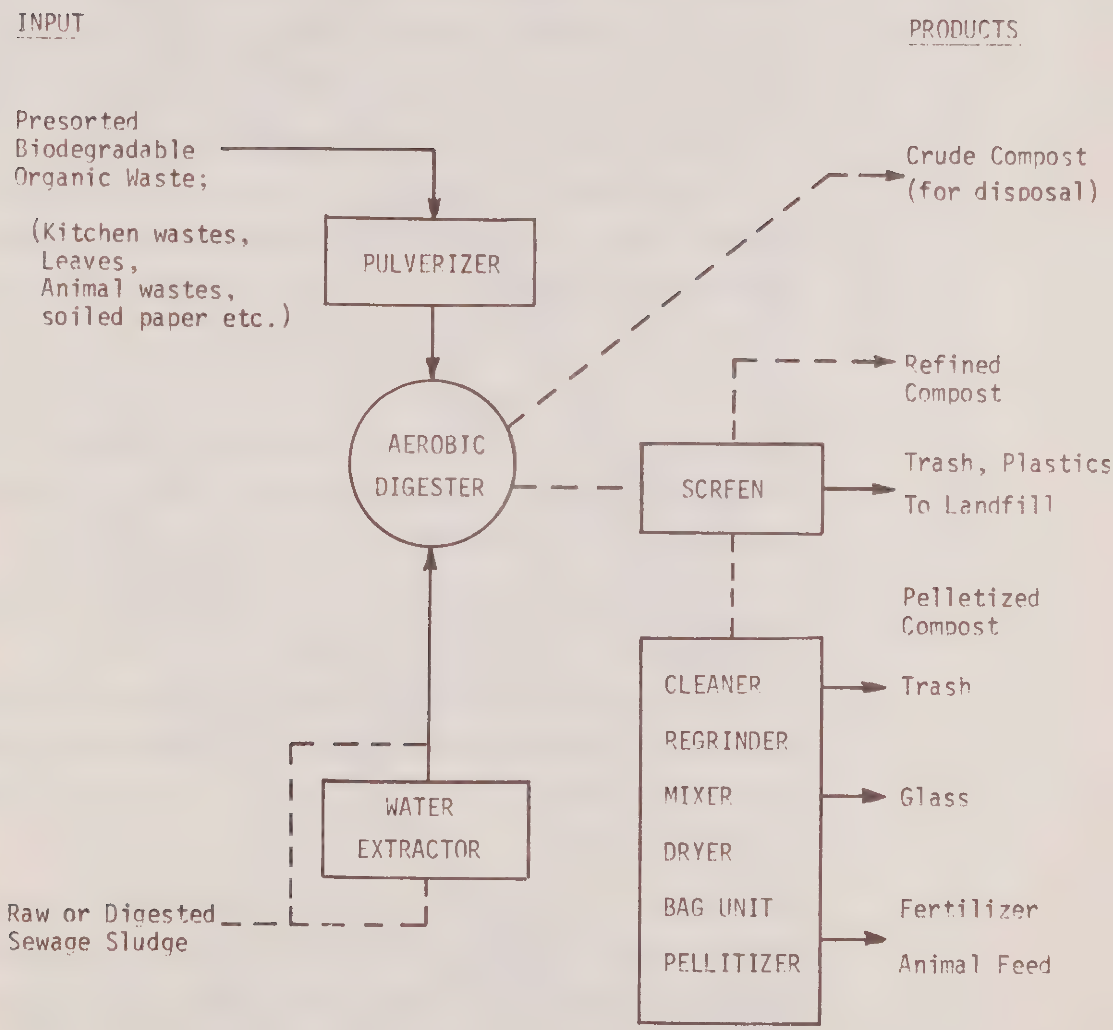
A general flowsheet for a composting operation is given in Figure 6.1; a specific example is shown in Figure 6.2. It will be noted that the waste is presorted to exclude large non-degradable items such as tires, refrigerators, building refuse, etc. This is accomplished either on site in a prior sorting operation or, more effectively, by ensuring, as in some communities, that only domestic refuse or kitchen wastes are collected for treatment in the composter.

The addition of raw or untreated sewage has been suggested in the flow diagram. This particular aspect will be considered in more detail in a later section but it should be noted that many (but not all) composting systems will ensure that "in refuse-sewage composting, several components of self purification appear with the result that a completely hygienic-pure final product results"[1]. The attractiveness of combining sewage and municipal waste lies in the reduction of the overall municipal capital charges for sewage and garbage treatment and the production of an enriched compost.

Reduction of the particle size and the homogenization of the material which results, appears to be a necessary step for the rapid and effective degradation of the waste. Most composting operations therefore include this step which may be accomplished by rotating rolls, hammer mills, shredders, rasps, or by tumbling mills. Hammer mills would seem to be the most popular choice although they incur relatively heavy maintenance and power costs. The technology and experience is available to enable a suitable choice to be made for any particular operation.

1. Knoll, K.H. Compost Science 2,1, 1961

FIGURE 6.1: GENERAL FLOWSHEET FOR A COMPOSTING OPERATION



The prepared waste material is then charged to the composting operation which may take several forms as described under the following headings:

1. Low-Cost Biostabilization

   Recently it has been suggested that open farm land could serve as a means of processing wastes either by loading the land to the limit of its ability to accept wastes without disrupting the growth decay cycle or by using the land for crops as well as waste treatment on a seasonal basis.

   It is stated that[1] "in practice, a given plot of land would receive a loading of ground raw refuse once or twice each year throughout the time in which the site is dedicated to waste disposal. The frequency of the loading would be a function of the rate of decomposition or stabilisation of the wastes in the soil. When the time comes to divert the land to another use loading would be stopped and the land allowed to recover. The non-degradable material remaining exposed on the soil would be removed and buried elsewhere.

   Inasmuch as only the top foot or two of the land would be involved, settling would be a negligible factor and the land could be put to its new use immediately".

   The results of tests with refuse loadings up to 400 tons per acre have not yet been announced, but this method would appear to provide a promising solution for small rural communities in a temperate climate.

2. Windrows

   The material is piled in heaps or rows approximately 6 ft high 10 ft wide and is turned to aerate the mass. The operation may be conducted in the open or under cover, but, since the process takes weeks to complete, the capital costs for buildings in most cases limits the choice to an outside operation.

   With pulverized material the problems concerned with odour and vectors are reduced and the operation takes between 6 to 12 weeks to provide a crude compost. The largest European

1. Hart, S.A. and MacFarland: Composting SERL Report No. 69-1 1969.

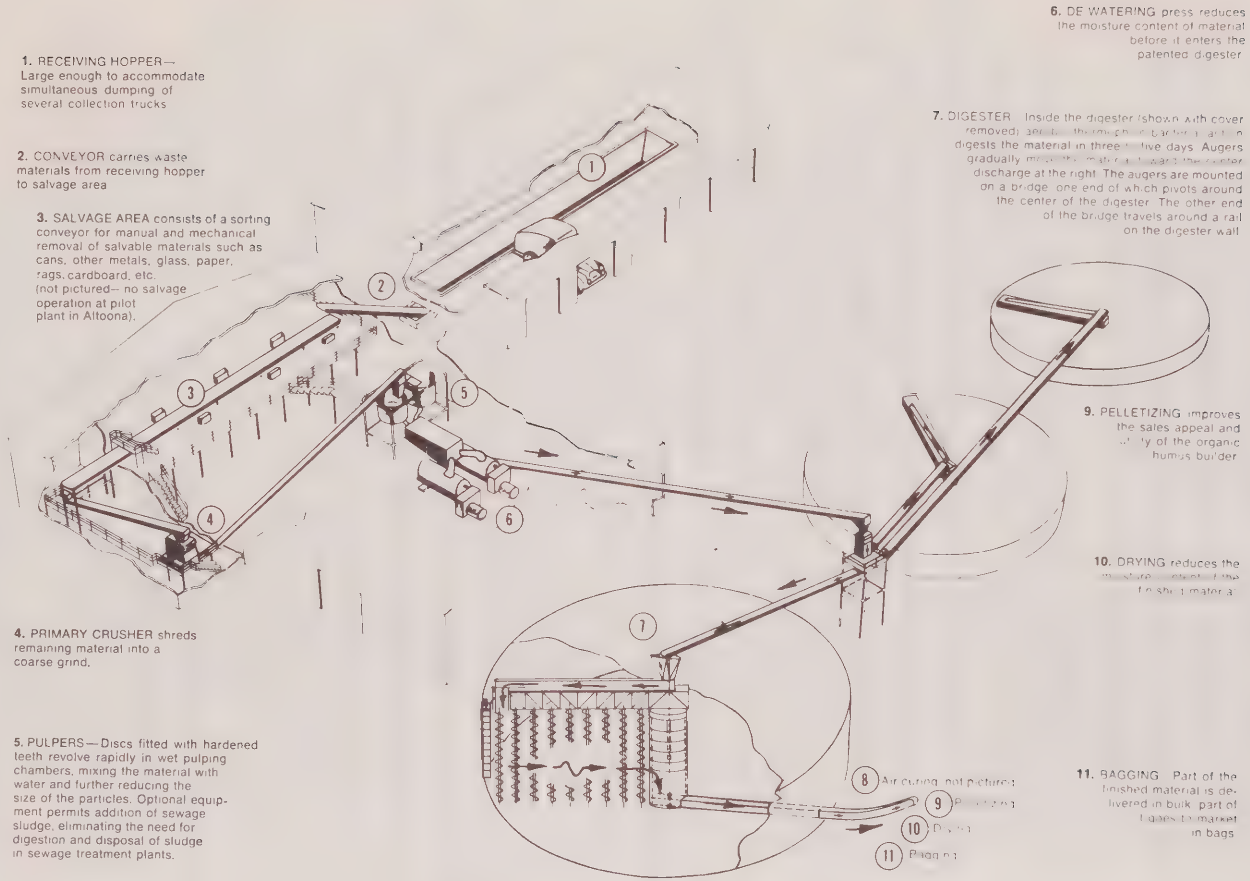



FIGURE 6-2: FAIRFIELD HARDY COMPOSTER SYSTEM
( AFTER FAIRFIELD ENGINEERING Co.)

composting plant operated by V.A.M. treats unpulverized material and by contrast takes 4 to 6 months to complete and odours and vectors are prevalent.

It may be concluded from the literature that the windrowing operation is not appropriate for the Canadian scene unless it is conducted on a small scale or under cover.

3. Mechanical Composters

Various units have been devised to simulate the windrowing procedure but to hasten the process by mechanical methods. These are well described in the literature[1] and no attempt will be made to compare all the designs which have been evolved. The best provide for the control of temperature and the degree of aeration to allow for the optimisation of the conditions necessary for the thermophilic bacterial process.

In these 'digesters' a good quality product can be obtained in three to six days with complete freedom from the problems of odour and vector nuisance.

The moisture content is found to be important and must be maintained between 40-70 percent by weight. Digestion temperatures range from 140 to 170 ¼F which together with other factors leads to the destruction or stabilization of many pathogenic agents. Although early studies[2] indicate complete pathogen destruction, further tests are being conducted and it would not be surprising to find that only partial destruction is achieved in some types of digesters in which there is inadequate mixing or temperature control. The digesters which have been employed in the U.S. are of particular interest since the Canadian conditions are very similar in many respects.

The drum 'Dano' digester which has found considerable acceptance in Europe has not met with much commercial success in the U.S.A. and the plants which operated these units have now been closed[3].

1. See Bibliography under 'Composting Plants'
2. Knoll, K.M. Compost Science 2 1, 1961.
3. Kane, D.E. 'Composting': Report SW7C U.S. Department of Health & Welfare 1969

The Metropolitan Waste Conversion Corporation unit which is operated by Lone Star Organics Inc. at Houston comprises long uncovered tanks which are filled in layers. The material is turned by rail mounted bucket elevators and is supplied with high pressure air to maintain suitable oxygen and temperature conditions[1]. The process takes approximately 6 days to complete. The $1.75 million Houston plant was designed to process 300 tons/day of garbage 6 days per week at a cost to the city of $4.51 per ton.

Another unit, devised by Naturizer Inc. with the assistance of the Lockheed-California Co., employs cells with steel apron conveyers 9 ft wide and approximately 200 ft long to move the material through the cells. The material is agitated and mixed at the discharge point of each conveyer. A positive supply of air does not appear to be utilised but temperature control is ensured. SACS Inc., organised by Lockheed and Naturizer, operated the San Fernando plant and signed an agreement with Westinghouse Electric to construct further reclamation and composting units[2]. The San Fernando and the original plant at Norman, Oklahoma, were closed after a short operating period. The latest plant using this digester is located at St. Petersburg, Florida. A twenty year contract was signed by the operators, the International Disposal Corp., for the disposal of 100 tons refuse per day, 6 days per week. The plant cost $1.5 million and the contract price to the city was $3.24/ton of refuse. After digestion the material is allowed to mature for a further two weeks.

The Hardy digester[3,4], developed by the Fairfield Engineering Co. of Marion, Ohio, appears to be the only digester in the U.S. which has been in continuous operation for more than five years and which is still operating. The first digester of this type

1. Hodges, C.R. Compost Science 7 3. 1967
2. Furlow, H.G. and Zollinger, H.A. Compost Science 4 4. 1964.
3. Anon. Publ. Cleansing 53, 12 and 594 (1963)
4. U.S. Patent No. 3, 114, 622.

at Altoona consists of a round tank made of concrete blocks, 37.5 ft in diameter and 10 ft high, fitted with a rotating bridge which agitates the material and moves it over a period of 3 to 5 days towards a central discharge port. Air is admitted through sparge pipes at a controlled rate to maintain both the oxygen level in the digester and the temperature level. A further large scale plant of this type has been constructed for the City of Puerto Rico.

A summary of the status and type of composting operations in the U.S.A. is given in Table 6.1.

In many of the processes described, the material produced by the digester or windrow operation can only be regarded as a crude product. Many of the original constituents of the garbage can be recognized and these together with broken glass seriously affect the market value and should be removed. Screening and air elutriation have been employed to extract plastic materials and glass. Depending upon the initial preparation of the raw material, secondary grinding, screening and magnetic separation have also been used.

In the Fairfield Hardy process the crude compost is screened to extract much of the plastic material. The compost may then be mixed with a suitable fertilizer to increase the nitrogen content and then can be pelletized. This product is dried and the glass separated by air elutriation. This pelletized form of compost is attractive[1] since it is readily handled and used and the artificial fertilizer content can be modified in quantity and composition to suit specific requirements. This same company is also vigourously exploring the market possibilities for other compost products.

It should be emphasized, however, that no secondary treatment is required if the crude compost is to be used for a sanitary landfill operation. No soil cover would be necessary in this operation and crude compost could be used to replace the soil cover used in existing landfill operations.

1. Fuller, W.H. Compost Science 6 3 1966.

TABLE 6.1: STATUS AND TYPE OF U.S. COMPOSTING PLANTS

| Location | Type | Capacity Tons/Day | Year Opened | Year Closed |
|---|---|---|---|---|
| Altoona, Pa. | Fairfield-Hardy | 25 | 1951 | Operating |
| Springfield, Mass. | Fraser Ericson | 20 | 1954 | 1962 |
| McKeesport, Pa. | Open Windrows | 100 | 1956 | 1957 |
| Sacramento, Cal. | Dano | 40 | 1956 | 1963 |
| Norman, Okla. | Naturizer | 40 | 1959 | 1964 |
| Phoenix, Ariz. | Dano | 300 | 1962 | 1965 |
| San Fernando, Cal. | Naturizer | 70 | 1963 | 1964 |
| Wilmington, Ohio | Open Windrows | 20 | 1963 | Operating |
| Boulder, Col. | Open Windrows | 100 | 1965 | 1968 |
| Elmira, N.Y. | Open Windrows | 70 | 1965 | Operating |
| Largo, Cal. | Metro Waste | 50 | 1966 | 1968 |
| St. Petersburg, Fla. | Naturizer | 100 | 1966 | 1968[1] |
| Mobile, Ala. | Open Windrows | 300 | 1966 | Not Known |
| Houston, Tex. | Metro Waste | 300 | 1966 | Operating |
| Johnson City | Windrows | 60 | 1967 | Operating |
| Gainesville, Fla. | Metro-Waste | 150 | 1968 | Operating |
| Puerto Rico | Fairfield-Hardy | 300 | 1970 | Operating |

[1] Scheduled to re-open

## COST ESTIMATES FOR COMPOSTING OPERATIONS

Cost data for processes which include a composting unit is generally reported as a total or total net cost for the whole operation. These figures include the charges for salvaging (if any), sorting, or segregation, disposal of non-compostable materials, pulverization, composting and compost refining.

A summary of the costs data for the entire process is given in Table 6.2, which shows the unit capital cost and the operating cost per ton of refuse. The data has been screened to ensure that the figures do not include amortization charges or income received from the sale of compost and salvaged materials or from the municipality in the form of a dumping fee. The data for the Dano, Dorr-Oliver, Vent Cells and Buhler-Dano processes have been derived from the data for European operations[1] using the E.N.R. index to evaluate 1970 costs for equipment and a factor of three to convert labour costs to Canadian levels. The data for the (J.K. Snell) process was derived from data given by Snell[2] with the equipment costs revaluated using the E.N.R. index. No attempt could be made to update the reported operating charges for this process which appear to be somewhat optimistic in comparison with the figures for other processes. The Fairfield Hardy data is based on a 1970 quotation, but it includes equipment and operating charges for the production of dried and pelletised compost.

Unfortunately, this data cannot be used to compare the costs of the different processes since the reported costs are for installations which provide for different types of product, raw refuse and regional conditions. All that can be concluded is that the unit capital cost per ton day of raw refuse will vary from $5,000 to $15,000 and the operating cost will be approximately $4.00 to $8.00 per ton, depending on the capacity, process selected and the individual requirements.

General figures for the value of compost and salvaged items are also highly dependent on the precise operating and regional conditions. A number of composting units have failed because overly optimistic

1. Kupchik, G.J. "Economics of Composting Municipal Refuse in Europe and Israel" J. San. Eng. Div., A.S.C.E., Dec. 1966 p. 41-56.

2. Snell, J.R. Compost Science 8, No. 1, p.17, 1967

TABLE 6.2: OPERATING & CAPITAL COSTS OF COMPOSTING PROCESSES

(Including handling, conveying, pulverizing and composting equipment corrected to 1970 costs using the ENR index.)

| TYPE | Tons Refuse Per Day | Approx 1970 Cost $Millions | Year Built or Quotation | $Cost Per Ton Day | Est Op[2] Cost $/Ton |
|---|---|---|---|---|---|
| Dano: | | | | | |
| 1 | 380 | 3.5 | 1964 | 9,200 | 3.80 |
| 2 | 179 | 1.03 | 1964 | 5,700 | 5.14 |
| 3 | 72.5 | 0.382 | 1958 | 5,100 | 3.70 |
| 4 | 17.2 | 0.129 | 1958 | 7,500 | 4.67 |
| 5 | 20.4 | 0.137 | 1958 | 6,700 | 7.36 |
| Dorr-Oliver: | | | | | |
| 6 | 2,700 | 5.30 | 1963 | 9,600 | 3.16 |
| 7 | 500 | 3.18 | 1961 | 6,400 | 5.10 |
| 8 | 288 | 2.43 | 1964 | 8,400 | 5.56 |
| Vent. Cells | | | | | |
| 9 | 104 | 1.160 | 1963 | 10,100 | 8.91 |
| 10 | 346 | 1.71 | 1964 | 4,950 | 8.42 |
| Buhler-Dano | 386 | 5.100 | 1963 | 13,200 | 7.35 |
| 'Metro' Design | 330 | 2.31 | 1967 | 7,000 | 7.00 |
| (Naturizer (Houston) | 100 | 2.04 | 1968 | 20,000 | - |
| J.R. Snell Design | | | | | |
| 1 | 800 | 4.32 | 1967 | 5,420 | 1.44 |
| 3 | 400 | 2.42 | 1967 | 6,080 | 1.72 |
| 5 | 200 | 1.31 | 1967 | 6,600 | 2.00 |
| 6 | 100 | 0.741 | 1967 | 7,400 | 2.32 |
| 7 | 50 | 0.411 | 1967 | 8,200 | 2.56 |
| 8 | 25 | 0.226 | 1967 | 9,050 | 2.86 |
| Fairfield-Hardy | | | | | |
| 1 | 100 | 1.5 | 1970 | 15,000 | 7.50 |
| 2 | 200 | 2.5 | 1970 | 12,500 | 6.00 |
| 3 | 300 | 3.2 | 1970 | 10,700 | 5.25 |
| 4 | 400 | 4.2 | 1970 | 10,500 | 4.25 |

[1] Excludes amortization and interest charges

[2] Also includes 'refining' of compost; also pelletizing and drying plant for Fairfield-Hardy.

estimates were made concerning the price and market for these products. Until a substantial market has been developed for compost it would seem that it might be appraised as having no commercial value in estimating the net cost of composting. As support for this argument it should be noted that data from fourteen plants indicates that none of the plants was able to cover its capital service costs and operating expenses through sales of compost and salvaged materials, and deficits ranged from $0.32 to $5.32 with an average net cost of $3.38 per ton of refuse[1].

In view of these uncertainties, it would appear to be instructive to estimate the approximate costs for composting for the conditions previously assumed in the evaluation of other methods of treatment and to investigate the costs of operation of a landfill site in conjunction with a composting unit which could provide the necessary cover material.

## THE COST OF PRODUCTION OF A FINISHED COMPOST

It is informative to calculate the production cost of compost in order to investigate the possible market for this material in Canada.

As in the case for costing a landfill operation this is a relatively easy matter if the individual situation has been defined. The analysis of the waste to be treated is of critical importance and, depending upon the type of composter employed, the precise tonnage to be handled could have a profound effect on the unit size chosen and hence upon the capital cost requirements for the process.

The following assumptions need to be made in order to estimate the minimum costs of composting in Canada:

1. The maximum quantity of compostable material in the municipal refuse will be treated and will be presumed to be 80 percent of the total quantity. A landfill operation will be used to dispose of the remainder such as refrigerators, tires, etc.
2. Of the material which will be handled by the composting unit

1. Kupchik, G.J. "Economics of Composting Municipal Refuse in Europe and Israel" J.San. Eng. Div., A.S.C.E., Dec. 1966 p. 41-56.

a further 15 percent will be rejected during the compost refining stage. This material which will consist largely of small metal objects, glass and plastics will be transported to the landfill site.

3. During the composting operation there will be a weight loss of one third, incurred by the oxidation of the organic matter.
4. The estimates will be based on the operation of Fairfield-Hardy units which are designed to accept 100 tons/day of ground waste. The total waste to be handled will be chosen to provide for the maximum operating tonnage for each unit on the basis of a 5 day week, 52 weeks per year.

The results and details of the calculations are given in Table 6.3. The unit cost figures for the production of compost are given in Table 6.4.

If the compost is to be made into a pelletized material, further pelletizing, drying, screening and bagging equipment is required. Approximate costs and data for the entire operation were obtained from the Fairfield-Hardy Co. and are reproduced in Table 6.5.

TABLE 6.5: COST DATA FOR FAIRFIELD HARDY SYSTEM WITH PELLETIZING, DRYING AND BAGGING

| Composter Capacity T/day | No. of Operators | Construction Cost | |
|---|---|---|---|
| | | Machinery $ | Building & Eng. $ |
| 100 | 11 | 1,100,000 | 400,000 |
| 200 | 18 | 1,900,000 | 600,000 |
| 300 | 25 | 2,400,000 | 800,000 |
| 400 | 32 | 3,000,000 | 1200,000 |

These figures do not allow for the operation of a small landfill site for the disposal of non-compostable materials or for the reclamation of materials separated during the operation. The overall costs of operating compost units to provide a pelletised product is given in Figure 11.1. It should be noted that the final costs do not make any

TABLE 6.3: APPROXIMATE COST OF COMPOST PRODUCTION

| ITEM | TOTAL WASTE 1000T/Yr | | | |
|---|---|---|---|---|
| | 32.5 | 65.0 | 97.5 | 130.0 |
| 1. TONNAGE: | | | | |
| Material Composted (1000T/Yr) | 26.0 | 52.0 | 78.0 | 104.0 |
| Material To Landfill (1000T/Yr) | 10.4 | 20.8 | 31.2 | 41.6 |
| Compost Produced (1000T/Yr) | 14.7 | 29.5 | 44.2 | 58.9 |
| Material Composted (T/Op.Day) | 100 | 200 | 300 | 400 |
| 2. CAPITAL COSTS ($1000) | | | | |
| Fairfield-Hardy Digesters | 300 | 600 | 900 | 1200 |
| Pulverizer & Shredders | 100 | 175 | 230 | 275 |
| Compost 'Refining' Equipment | 50 | 60 | 100 | 120 |
| Loading Equipment | 60 | 75 | 80 | 95 |
| Building, Engineering & Site Development | 200 | 300 | 400 | 500 |
| Contingency @ 10 % | 71 | 121 | 171 | 219 |
| Landfill Capital Costs | 77 | 153 | 193 | 258 |
| Total Approximate Cost | 858 | 1484 | 2074 | 2667 |
| 3. LABOUR COSTS ($1000/Yr) | | | | |
| Supervisor @ $6.00/hr | 12.5 | 12.5 | 12.5 | 12.5 |
| Composting Operators @$3.50/hr | 36.5(5) | 51.5(7) | 65.7(9) | 80.3(11) |
| Scaleman @ $3.50/hr | 7.3(1) | 7.3(1) | 7.3(1) | 7.3(1) |
| Loading Operators @ $5.00/hr | 20.8(2) | 31.2(3) | 42.0(4) | 42.0(4) |
| Mechanic & Helper @ $8.50/hr | *8.8(2) | *8.8(2) | 17.7(2) | 17.7(2) |
| Landfill Site Labor | *10.0(2) | *20.0(3) | 27.0(3) | 33.5(4) |
| Overheads @ 40 % | 38.4 | 52.5 | 68.9 | 77.2 |
| Total Labor Charge | 134.3 | 183.8 | 241.0 | 270.5 |
| No. of Personnel | 11 | 15 | 20 | 23 |
| 4. OPERATING COSTS ($1000/Yr) | | | | |
| Power & Services | 14.5 | 29.0 | 43.5 | 58.0 |
| Maintenance @ 5 % Fixed Charge | 40.9 | 70.2 | 97.7 | 114.4 |
| Amortization (9 1/4% 20 years) | 99.0 | 170.0 | 238.0 | 308.0 |
| Total Labor Costs | 134.3 | 183.8 | 241.0 | 270.5 |
| Total Operating Cost | 318.7 | 453.0 | 613.2 | 750.9 |

*Part-time only

TABLE 6.4: UNIT FIGURES FOR COMPOST PRODUCTION

| ITEM | TOTAL WASTE 1000T/Yr | | | |
|---|---|---|---|---|
| | 32.5 | 65.0 | 97.5 | 130.0 |
| 1. Quantity (T/Op.Day) | | | | |
| Total Waste | 124.0 | 250.0 | 372.0 | 500.0 |
| Compost Produced | 56.5 | 113.0 | 170.0 | 226.0 |
| 2. Unit Capital Cost ( $/Ton Waste Per Day) | 6,900 | 5,900 | 5,550 | 5,350 |
| 3. Unit Operating Costs | | | | |
| (i) $/Ton Raw Waste | 9.80 | 7.00 | 6.30 | 5.80 |
| (ii) $/Ton Compost | | | | |
| a) With No Subsidy | 21.60 | 15.40 | 13.90 | 12.70 |
| b) With $1/T Waste Subsidy | 19.40 | 13.20 | 11.70 | 10.50 |
| c) With $2/T Waste Subsidy | 17.20 | 11.00 | 9.50 | 8.30 |
| d) With $3/T Waste Subsidy | 15.00 | 8.80 | 7.30 | 6.10 |
| e) With $4/T Waste Subsidy | 12.80 | 6.60 | 5.10 | 3.90 |

allowance for the cost of artificial fertilizers which might be added to the compost, neither do they reflect any return for salvaged material.

INTEGRATED COMPOSTING LANDFILL OPERATION

The composting operation might be regarded as a 'sanitizing' operation and not as a process for the production of a saleable compost. A crude compost product might be made from the putrescible refuse fraction and used as cover for trash and inert materials to provide a truly sanitary landfill operation. In view of the high cost of providing the cover material for a landfill operation and the desire to improve the stability of a landfill site, this integration of a composter and landfill operation would appear to need investigation.

An integrated operation of this kind would seem to offer most of the advantages claimed for the pulverization method but in addition leachate problems would be minimized, the deep crude compost cover will promote the rapid growth of vegetation and the problem of supply and storage of cover material would be solved. There would also appear to be a natural balance between the material which could or should be composted and the inert waste fraction, thus ensuring an adequate supply of crude compost for cover use at all operating levels.

An an example, it is believed that if the total waste amounted to 50,000 tons per year at least 50 percent of this could be composted which would provide approximately 16,500 tons of crude compost. For an 8 ft cell depth 1.2 cu yds of top cover is required per ton of waste fill (see Table 6.6). Thus, for a compaction density of 30 lb per cu ft, only 960 lbs of crude compost would be required per ton of refuse, whereas 16,500 x 2,000/25,000 = 1,320 lb of compost are available.

The costs of this integrated process at different operating levels would appear to be worth investigating. The calculations and results which are summarized in Table 6.6 are based on the following assumptions.

1. Clean materials, free from putrescibles arising in bulk from commercial or industrial sources, will be trucked directly to a sanitary landfill site.

TABLE 6.6: COSTS FOR INTEGRATED COMPOSTING LANDFILL OPERATION

| ITEM | Total Waste 1000T/Yr | | | |
|---|---|---|---|---|
| | 52 | 104 | 156 | 208 |
| 1. TONNAGE | | | | |
| Waste to Landfill 1000 T/Yr | 26.0 | 52.0 | 78.0 | 104.0 |
| Waste to Composter 1000 T/Yr | 26.0 | 52.0 | 78.0 | 104.0 |
| Waste to Composter Tons/Op.Day | 100 | 200 | 300 | 400 |
| Crude Compost Produced | 17.3 | 34.6 | 51.9 | 69.2 |
| 2. CAPITAL COSTS: $1000 | | | | |
| Compost Operation | 726 | 1260 | 1610 | 2070 |
| Landfill Land Costs: 20 years | 126 | 252 | 378 | 505 |
| Landfill Equipment & Dev. Costs | 73 | 73 | 98 | 98 |
| Total Approximate Cost | 925 | 1585 | 2086 | 2673 |
| 3. LABOUR COSTS: $1000/Yr | | | | |
| Supervisor @$6.00/hr | 12.5 | 12.5 | 12.5 | 12.5 |
| Composting Operators @$3.50/hr | 36.5 | 51.5 | 65.7 | 80.3 |
| Scaleman @$3.50/hr | 7.3 | 7.3 | 7.3 | 7.3 |
| Truck Operator @$3.50/hr | 7.3 | 7.3 | 7.3 | 14.6 |
| Mechanic & Helper @$8.50/hr | 4.4 | 8.8 | 13.2 | 17.7 |
| Landfill Site Lab. | 23.2 | 29.2 | 29.2 | 39.6 |
| Overheads @ 40 percent | 36.5 | 46.5 | 54.0 | 68.8 |
| No of Personnel | 10 | 13 | 16 | 21 |
| 4. OPERATING COSTS: $1000/Yr | | | | |
| Power & Services | 14.5 | 29.0 | 43.5 | 58.0 |
| Maintenance @ 5 % Fixed Charge | 46.2 | 79.2 | 104.3 | 133.7 |
| Amortization, 9 1/2 %, 20 years | 102.0 | 177.0 | 232.0 | 298.0 |
| Total Labour Costs | 127.7 | 163.1 | 189.2 | 240.8 |
| Total Operating Cost | 290.4 | 448.3 | 569.0 | 730.5 |
| 5. UNIT COSTS | | | | |
| Unit Capital Cost $/T.Day | 4,620 | 3,960 | 3,480 | 3,340 |
| Unit Operating Cost $/T.Waste | 5.65 | 4.30 | 3.64 | 3.50 |

2. The fraction contaminated with putrescible or biodegradable material is 50 percent of the total waste and will be composted.
3. The crude compost product will not be refined and will be used as cover material for the landfill site operation.
4. The composter will be sited at the landfill site.
5. The operating levels for the calculation will be chosen to match the maximum capacities for standard Fairfield-Hardy digesters.

The results of these calculations indicate that an integrated composting-landfill operation could be of economic interest.

## MULTI-WASTE AEROBIC DIGESTION

Many biodegradable organic wastes can be treated by an aerobic, thermophilic bacterial digestion process. Thus sewage, animal, agricultural and some industrial wastes could be treated together with municipal waste in mechanical digesters similar to those previously described for a composting operation. The product would be similar to a compost in nature but would contain a higher proportion of nitrogen and phosphorous which could make the material even more attractive as a soil conditioner.

The disposal of animal, agricultural and some industrial wastes could be a very attractive feature for some communities, but of universal interest is the possibility of combining the disposal of raw sewage and putrescible domestic wastes in one unit. For this purpose an aerobic digestion process has distinct advantages over the anaerobic process now employed in sewage treatment plants. The material is treated in the form of a wet solid for approximately 5 days and not as a dilute solid suspension for periods up to 21 days. The equipment is therefore more compact and could be less expensive per pound of solid treated. The product should not present any disposal or utilisation hazards in contrast to the digester sludge which in some communities is banned as a soil conditioner. Finally, since raw sludge is said to lose "50 to 80 percent of its total nitrogen and phosphorous

to the supernatent during the anaerobic process"[1], these materials might be retained by an aerobic process and thereby reduce the nutrient pollution of the water bodies.

Although there have been many articles published on the subject of the combined aerobic digestion of sewage sludge and refuse there are very few communities in the world which practise this method. Prejudice in favour of standard sewage systems might partly account for this but the practical problem of separating sewage solids from the large volumes of sewage water is probably a more realistic explanation.

The pathogenic hazards involved in treating sewage sludge in this manner do not appear to be insurmountable and under well controlled conditions may be less than those now experienced in conventional systems. "There is ample evidence that the causative organisms of faecal-borne diseases are destroyed by aerobic composting if temperatures in the thermophilic ranges are maintained for a sufficient time and all the material is subject to these temperatures"[2]. As emphasised by Davies[3], it is important to realise, however, that not all aerobic processes fulfil these conditions. Equipment and operating procedures, therefore, should be considered with great care to avoid any health hazards to the operators and public. This aspect becomes of special importance if general acceptance of the dual processing of garbage and sewage is to be developed.

Wiley[4] reports on the proposal to incorporate sewage sludge in the experimental windrow composting process at Johnson City. This project, sponsored by the Tennessee Valley Authority and the Public Health service, appears to be the first large scale investigation of this kind on this continent. Further details are provided in a later article[5] but the final results of the study have not been received.

Westrate[6], in commenting on this investigation, underlined the problems and disadvantages. He indicated that filtration of the sludge, the addition to the ground refuse, the possible retardation of the

1. Snell, J.R. Compost Science, 8, No. 1 p. 26, 1967.
2. Gotaas, H.B. "Composting" (Sanitary Disposal and Reclamation of Organic Wastes), World Health Organization, Geneva, Switzerland, 1956.
3. Davies, A.G. Compost Science 1, Mo. 3 p. 9 1960.
4. Wiley, J.S. Compost Science 8, Mo. 1 p. 22 1967.
5. Anon. Environmental Sc. and Tech. 2, 8 p. 589, 1968.
6. Westrate, W.A.G. Compost Science 8, Mo. 1 p. 24, 1967.

digestion process and health hazards represented serious problems. It was also stated that with present equipment the total quantity of sludge from a community could not be processed with the refuse since the moisture content of the digester feed could not exceed 50 to 60 percent.

It is unfortunate that sufficient data is not available to determine the approximate operating costs for the dual treatment of sewage and domestic waste. This process has many virtues and it is to be hoped that further work will demonstrate its feasability and economic possibilities.

## DISCUSSION

The production of compost for agricultural use has an idealistic appeal but there is no evidence that a profitable market is available in Canada at this time even in the pelletised form. On the other hand an integrated compost landfill operation which assumes that the compost will be used solely as a cover material in a sanitary landfill operation has many attractions. For this type of operation it may be concluded that:

1. A composter-landfill process will have many of the advantages of a pulverization-landfill process. In addition, the landfill site can be rapidly converted to a green park area, probably on an annual basis, and there should be almost complete freedom from contamination of groundwater with leachate.
2. The operating cost of such a process would be higher than a conventional landfill operation but would be of the same order as a pulverization-landfill process. The initial capital charges are higher, however, than both operations but these might be offset by the increased final value of the landfill site or reduced transportation charges.
3. Additional benefits might be obtained by utilizing the compost unit for the disposal of sewage materials and other organic wastes.
4. Capital investment and operating charges for mechanical composting units increase very rapidly for units below 100tons/day

capacity and unless these units are operated on a regional basis they cannot be justified for the smaller communities.

A composting operation, if compost cannot be sold, should be regarded as a valuable means of 'sanitizing' solid organic wastes. In the field of solid waste treatment it might be regarded as being analogous to the sewage plant treatment of waste water. Composting therefore deserves further attention as a 'biostabilization' process for the treatment of all types of organic wastes and future attention should be directed toward the development of processes for small communities and the assessment of the total organic waste disposal problem.

The product of these processes could be made into a high grade compost which has already been proved to be highly beneficial in increasing soil fertility[1]. To assist in the development of consumer acceptance Kane[2] recommends that compost standards should be developed, educational programs should be sponsored and that further evaluations of processes, soil requirements and methods of utilization should be encouraged.

Composting as a biostabilization process and as a means of producing a valuable soil conditioner merits far greater attention in Canada. Undoubtedly it will become one of the most important methods of satisfactorily treating organic biodegradable solid wastes. and could eventually provide a method for the combined treatment of municipal wastes and sewage.

1. Knoll, K.D. Compost Science 2, 1, 1961
2. Kane, D.E. "Composting": Report SW7C U.S. Dept. H.E.W. 1969.

# CHAPTER 7

## NEW PROCESSES

During the last five years a number of new processes for the treatment of municipal waste have been investigated. Many of these are still in the research and development stage but a few are at the point at which pilot or full scale operations will be attempted. Meaningful data for these processes is difficult to obtain and this chapter will therefore be devoted more toward a review of their outstanding characteristics than to an economic analysis. The processes of anaerobic digestion, pyrolysis, fibreclaim, hydrolysis and compaction will be considered.

## ANAEROBIC DIGESTION OF SOLID WASTES

Anaerobic digestion is the process of biodegradation of organic materials in the absence of oxygen. Sewage solids suspended in water are treated in this manner in digesters which have a retention period of approximately 21 days. During this period the insoluble solids are reduced to soluble constituents and a solid residue, representing approximately 65 percent of the initial solids feed. A combustible gas, consisting largely of methane, is generated in the process and is utilized in the larger plants for heating and power generation. A flowsheet for a typical process based on average conditions for a population of 50,000 is given in Figure 7.1.

The flowsheet has been drawn for the operation of equipment commonly installed for a community of medium size in Canada. Whereas a detailed consideration of sewage disposal units is not within the scope of this report it should be noted that:

1. The amount of suspended solids transported in the sewer system is relatively low at 0.375 lbs per capita per day in relation to the quantity of other solid municipal wastes.

2. The sludge produced, per capita per day, is approximately 2.80 lbs which is equivalent in quantity to the amount of domestic waste. This sludge contains about 7.0 percent solids and requires either disposal facilities or processing to produce an organic fertilizer.
3. Unless a sophisticated treatment process is installed, the soluble constituents of the raw sewage and those generated by the sewage treatment are discharged directly into a water body.
4. Industrial wastes in the sewage can cause operating difficulties and in many cases are discharged from the plant in an untreated, if diluted, form.

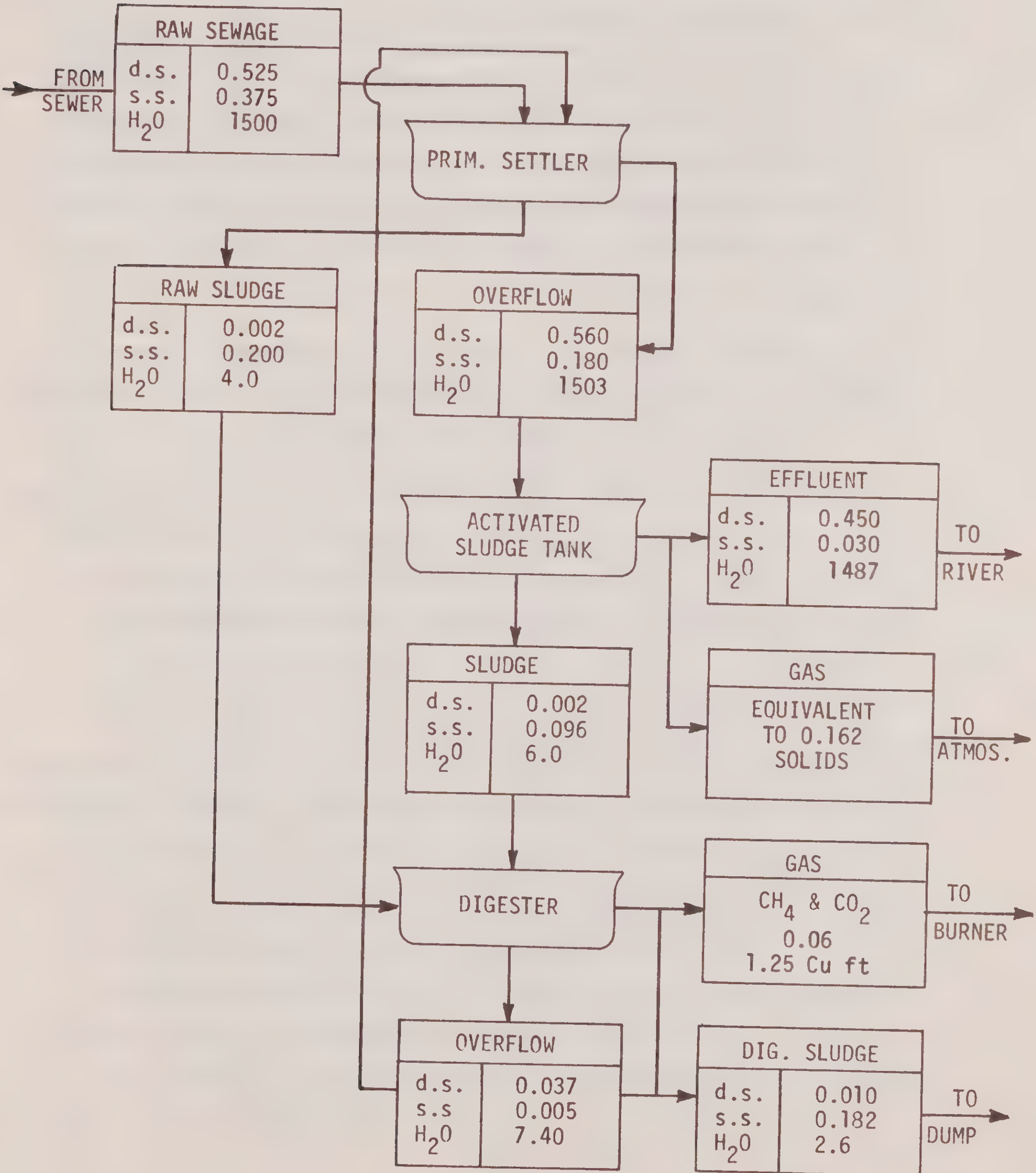
In briefly reviewing the overall performance of a sewage system one is forced to conclude that at a cost of approximately $250 per capita for plumbing, sewers and treatment plant most municipalities have only developed a sophisticated method of collection of solid and liquid wastes. The problems of the ultimate disposal of the solids and the dissolved solids remain to be solved.

One approach to improving the cost effectiveness of the present and future more sophisticated sewage disposal systems is to include the treatment of putrescible refuse. This could be accomplished by enforcing the use of garburators or their equivalent for the disposal of putrescible wastes, such as kitchen refuse. This might reduce the cost of garbage collection, provide for a more sanitary means of disposal and permit the remaining domestic wastes to be treated or buried without the hazards and problems now encountered. Some cities are seriously considering this proposition, whereas others are investigating the possibility of separate collection of putrescibles and their grinding and addition to the sewage stream at central locations. In either method the solid disposal loading on the treatment system is increased and work is now proceeding to determine the feasability of the process and costs which are incurred.

Klein and Chan[1] emphasize that "an integral and attractive aspect of this concept is the use of hydraulic transport". They report that experiments conducted by the Los Angeles County Sanitation

1. Klein, S.A. and Chan, D.B. "Anaerobic Digestion" SERL Report 69-1.

FIGURE 7.1: SEWAGE TREATMENT FLOW DIAGRAM




Key d.s. - dissolved solids, s.s. suspended solids
All quantities given in lbs per capita.

districts confirm that the sewers provide an effective means of transport but indicate that existing treatment facilities would have to be expanded in terms of grit removal chambers, primary sedimentation tanks, and increased digester capacity.

To obtain design data, Klein and Chan have investigated the anaerobic digestion process on a laboratory scale. They report that anaerobic digesters can be designed to operate with a ground garbage feed and that existing digesters can tolerate up to 76.5 % garbage as a mixed garbage-sewage sludge feed. These preliminary results confirm the early work in this field which is summarized by Golueke[1].

## THE PROCESS

Although the process is still in the development stage the operation for the dual disposal of putrescible refuse and sewage sludge can be defined and evaluated on economic grounds.

The initial stage is concerned with the segregation of the putrescible fraction which amounts to approximately 15.5 percent of the domestic waste. This is most easily accomplished by the householder and this fraction can be directly introduced into the sewers using domestic garburators. Full advantage of the sewer transportation system would be obtained in this way and the collection costs for municipal wastes could be considerably reduced. It is possible, for example, that weekly, instead of bi-weekly, collections could be introduced for the non-putrescible refuse, thus reducing the collection costs to a far greater degree than a proportional decrease related to the content of putrescibles in the waste. Some cities are contemplating the introduction of by-laws to require the installation of garburators, but it is doubtful whether this ideal solution will find widespread acceptance. The alternatives are to collect putrescibles separately or separate them after collection and then grind them for sewer disposal. In this approach, however, the virtues of sewer transportation are largely negated unless the system is to be operated in a large city with many disposal points. At the best, this first stage could reduce the municipal collection costs by 15 to 40 percent, but at the

1. Golueke, C.G., Compost Science 2 No. 2 p. 9 1961.

worst with a single central grinder it could increase the collection costs. This aspect needs careful and individual evaluation for each community although for new communities it would appear that the compulsory installation of garburators promises to provide a favourable solution.

The second stage is the anaerobic treatment of the solids in a digester. The conduct of this operation will be dependent upon whether the sewers have been used for transport, and a mixed garbage-sewage sludge material is to be treated, or whether the garbage is separately collected or sorted and ground on the digester site. Sufficient data is available to predict, apprxoimately, the costs of this operation.

The third stage is the removal and disposal of the undigested solids. These could present pathogenic hazards and must be treated as the equivalent of digested sewage sludge.

In estimating the costs of treatment by an aerobic process it will be assumed that:

1. All putrescible wastes will be ground and discharged at source into the sewer. (This represents the best possible case for disposal by this method, although it can only be practiced in a few communities.)
2. The non-putrescible fraction will be collected less frequently and will be disposed of by a landfill operation. The collection costs will be assumed to be reduced by $2/ton from $8/ton for a community whose municipal wastes amount to 50,000 tons/year.
3. The quantity of putrescible material will be equivalent to 15.5 percent of the quantity of domestic waste which amounts to 25,000 tons/yr. This is equivalent to 0.425 lbs per capita per day of putrescible material.
4. A separate or new digester will be required for the extra loading on the sewage facilities.
5. Disposal of the digested solids will be disposed by a sanitary landfill operation.

CAPITAL & OPERATING COSTS FOR ANAEROBIC DIGESTION OF PUTRESCIBLES

The following calculations have been based on those presented in the SERL Report (No. 69-1).

(i) Digestion:

If the daily flow to the digester is assumed to be 2 gallons per pound of solid then the total daily flow will be 41,400 gallons. Using the data estimated in the SERL report the capital cost will be approximately \$29,000 with an operating cost of \$1,350 per year. Maintenance and miscellaneous costs are reported to average \$2,000 per year per million gallons per day plant capacity and therefore this item will amount to approximately \$828 per year.

(ii) Value of Digester Gas:

The gas has been optimistically valued at 5 cents per 100 cu ft and the amount produced is estimated to be 7.9 cu ft per lb of 'volatile solid'[1]. For these conditions and assuming 0.75 lb of volatile solids per lb of garbage the value of the gas would be approximately:

$$7.9 \times 0.0005 \times 25{,}000 \times 2000 \times .155 \times 0.75$$

$$= \$23{,}000 \text{ per year}$$

(iii) Landfill Charges:

If a 75 percent reduction of the garbage fraction is accomplished in the digester then the additional digested sewage solids to be removed and disposed will be approximately 970 tons per year. The total solid wastes to be handled by a landfill operation will then be 52,170 tons per year. The cost of this operation (see Chapter 3) will be approximately \$2.35 per ton. The capital costs associated with the landfill operation will be approximately \$288,000 as previously estimated for an operation of 50,000 tons/year. The total capital and operating costs are therefore as follows:

1. SERL Report 69-1, p. 72

| | |
|---|---|
| Capital | |
| Anaerobic digester | $ 29,000 |
| Landfill operation | 288,000 |
| Total | $317,000 |
| Operating (including amortization) $/yr | |
| Digester operation | 5,398 |
| Landfill operation | 169,000 |
| Total Charges | 174,398 |
| Credit for gas produced | 23,000 |
| Credit for reduced collection charge | 110,000 |
| Total credits | 133,000 |
| Net operating costs | |

The net cost per ton of municipal refuse (including amortization charges) is therefore

$41,398/50,000 = $0.828 per ton.

DISCUSSION

1. The anaerobic digestion process might be an attractive proposition for a new community in which the use of garburators can be enforced. It should be noted, however, that a landfill site of normal proportions will have to be operated and that the attractiveness of the proposal lies largely in the reduction of the collection charges.
2. For an existing community, in which the universal use of garburators cannot be expected, the anaerobic digestion process of the putrescibles alone offers little economy. The figure for the sale of digester gas might be found to be purely fictitious and the charges for garbage collection and disposal by landfill will be substantially unaffected by the introduction of this process. Indeed, it is possible that an analysis of this situation for a particular community would reveal that additional costs would be incurred arising from the charges for the sorting and central grinding operations.

3. The problems associated with a landfill operation remain and might be compounded by the disposal of larger quantities of digested sewage-garbage solids from the anaerobic digester.
4. The striking effect of the decrease in collection costs on the disposal charge re-emphasises the need to re-examine methods of collection with the prospect of using the savings obtained to improve the methods of disposal.

It is concluded that the anaerobic digestion process of the putrescible content of domestic waste does not offer an attractive solution for an existing community of medium size in Canada and is of no interest to rural communities. When more detailed information becomes available a further evaluation might profitably be undertaken to examine the situation for cities and for the digestion of a greater fraction of the municipal waste.

## PYROLYSIS OF MUNICIPAL WASTE

Pyrolysis, or the destructive distillation of organic materials, has been practised for many centuries. Charcoal from wood and coke from coal are two well known products which are made in this manner by the high temperature decomposition of materials in the absence of oxygen.

Recently the possibilities of this process have been investigated for the treatment of kraft black liquor[1] and for the disposal of automobile tires[2]. As a natural development, the treatment of domestic municipal and industrial wastes is now being investigated[3,4].

Very little practical information is available since the process is in the development stage at the present time but the products of the process are known to be a potentially useful solid residue, a combustible gas, tars, light oils and an aqueous liquor.

1. Brink, D.L. et al TAPPI 50 (6) 276-285 June 1967
2. Wolfson et al. U.S. Bur. Mines, RI 7302, 1969
3. SERL Report 69-1
4. Sanner et al U.S. Bur. Mines, RI 6428,1970.

F.P. Wright and Associates of Chattanooga have recently designed a $65 million pyrolysis plant for Atlanta, Montgomery, and Birmingham to process 1.2 million tons of refuse per year rising eventually to a capacity of 5.0 million tons per year. On this large scale, it is reported by 'Air and Water News' that this process is so attractive that cities could be paid over $6.00 per ton for refuse. Hercules Inc. is also designing a treatment plant for New Castle County, Del. which will incorporate a pyrolysis unit.

PROCESS DESCRIPTION

From the preliminary reports it would appear that the inorganic material in the refuse should be partially separated before pyrolysis. This would reduce the thermal requirements for the operation and upgrade the solid residue by reducing its ash content. In practice this calls for the separation or segregation of the glass, metal and the 'inert' content of the waste which could either be reclaimed or used for 'fill'.

The organic fraction of the waste including plastics, paper, household garbage, rubber products and other material which cannot be economically separated would then be charged into the pyrolysis reactor. The reactor would probably be operated in a temperature range of 900 to 1200 °C to improve the conversion of carbon to a combustible gas according to the reaction:

$$C(s) + H_2O(g) \rightleftarrows CO(g) + H_2(g)$$

The thermal requirements to raise the feed material to this elevated temperature and to maintain the reaction temperature might be accomplished by either the partial combustion of the feed in a preheater section or by utilizing a fraction of the combustible gases produced in the pyrolysis process. The gases arising from the pyrolysis are then cooled and the liquid fractions separated by decantation, solvent extraction and distillation. The remaining gas might then be scrubbed with sulphuric acid solution to remove the ammonia content before it is utilized for its heating value.

To provide some indication of the nature of the products the

following data is reproduced from that reported by Sanner et al[1] for pyrolysis of domestic waste at 900 °C.

Composition of Refuse:

The sample was obtained from the Altoona Plant, Marion, Ohio, which treats municipal refuse containing only a small fraction of glass and metals.

| Proximate Analysis | % | Ultimate Analysis | % |
|---|---|---|---|
| Moisture | 43.3 | Hydrogen | 8.2 |
| Volatile matter | 43.0 | Carbon | 27.2 |
| Fixed Carbon | 6.7 | Nitrogen | 0.7 |
| Ash | 7.0 | Oxygen | 56.8 |
| | | Sulphur | 0.1 |
| | | Ash | 7.0 |

Btu per pound refuse 4,827

The Products:

| | Yield/Ton Refuse |
|---|---|
| Solid Residue | 186 lbs |
| Gas | 17,741 cu ft |
| Tar | 0.5 gals |
| Aqueous Liquor | 113.9 gals |
| Ammonium Sulphate | 25.1 lbs |

Solid Residue:

The residue "is a lightweight, flaky char and all samples could be readily sieved to remove extraneous materials such as bottle caps, tin can lids and aluminum". The analysis is as follows:

| Proximate Analysis | % | Ultimate Analysis | % |
|---|---|---|---|
| Moisture | 1.0 | Hydrogen | 0.3 |
| Volatile | 4.7 | Carbon | 36.1 |
| Fixed Carbon | 31.7 | Nitrogen | 0.5 |
| Ash | 63.6 | Oxygen | - |
| | | Sulphur | 0.2 |

The calorific value was reported as 5,260 Btu/lb.

Gas:

The basic constituents of the gas, as percent by volume, after scrubbing with sulphuric acid, are:

| | | | |
|---|---|---|---|
| Hydrogen | 51.91 | Carbon Dioxide | 11.42 |
| Carbon Monoxide | 18.16 | Propylene | 0.32 |
| Methane | 12.66 | Butane | 0.44 |
| Ethylene | 4.68 | Trace gases | 0.41 |

The calorific value of this gas is 440 Btu/cu ft.

1. Sanner et al U.S. Bur. Mines, RI 6428, 1970

## OPERATING COSTS

It is premature to attempt to estimate equipment costs for the pyrolysis process but it would appear that they will be of the same order as those for the incineration process. Savings in equipment purchases for pollution abatement and reduced engineering costs will be compensated by expenditures for the gas and liquor treatment operations.

A profitable market might be found for the solid residue as a fuel, absorbent, soil conditioner or filter medium. As a fuel it might be valued at $3.00/ton which would provide a minimum revenue of 28 cents/ton refuse. If after internal usage 80 percent of the gas produced is available for sale this might be valued at 20¢ per 1000 cu ft. This would provide a revenue of $3.54 per ton of refuse. The preliminary studies indicate that the aqueous liquor has little value and the cost of its treatment before disposal will partially offset the total approximate revenue of $3.82 per ton of refuse. Additional revenues may be obtained, however, from the sale of recovered glass and metals. It is believed, therefore, that the prospect of a $6 revenue for refuse is an optimistic estimate of the attractiveness of this process, but much will depend on the sales value of the gas.

## DISCUSSION

The process of Pyrolysis for the treatment of municipal refuse offers the following potential attractions:

1. Air pollution hazards are almost entirely eliminated.
2. The Products produced are potentially useful as new sources of energy and hydrocarbons.
3. Most of the least desirable materials from the viewpoint of incineration can be treated by pyrolysis and they serve to upgrade the gaseous and liquor products. For example, plastics and rubber which create air pollution hazards in an incineration process increase the calorific value of the gas.

These attractions must be weighed against the potential disadvantages of the process which are:

1. The complexity and cost of the operation which will probably be of the same order as an incinerator operation if gas, liquid

and solid treatment systems are included.

2. The treatment and disposal of the aqueous liquor product could present a severe water pollution abatement problem.
3. The desirability of providing a means of separating much of the inert material prior to pyrolysis involves complex equipment or high labour costs.

Although this process merits far greater attention than it has yet received it cannot be considered as a viable alternative at the present time, for small communities, unless the unit were to be constructed to serve a number of communities on a regional basis. On a large scale, pyrolysis units are likely to be cheaper to build and easier to operate than incinerators and can be designed with high thermal efficiencies. Large units can be built to handle 10,000 tons per day and at these capacities the treatment costs can be reduced to \$1.25/ton of refuse .

## FIBRECLAIM

This system, which is designed to recover paper fibre from solid waste, has been developed by the Black Clawson Company, Shartle-Pandia Divisions, Middleton, Ohio. This company, which has manufactured paper pulp machinery for many years, has been intensively working to develop a reclamation system using the machinery with which they are most familiar.

This unique process, developed by this company, relies entirely upon wet separation techniques and for most stages of the operation the equipment is very similar to that which has proved to be satisfactory for corresponding operations in the pulp and paper industry. To prove the practicality of the process a pilot plant was constructed at Middleton, Ohio with assistance of a grant from the U.S. Department of Health, Education and Welfare. This has provided a convincing demonstration of the possibilities of the process and has allowed the company to investigate the markets for the products. A full scale unit is to be constructed under the Bureau of Solid Waste Demonstration Grant 2 906 E 00194-02, for the City of Franklin, Ohio,

to treat 54 tons of refuse in an 8 hr day.

## PROCESS DESCRIPTION

A demonstration of the pilot plant was attended by the authors of this report and it is believed that the process is adequately described by the following excerpt from the Black Clawson literature and by Figure 7.2.

> "The incoming refuse is first dumped into a storage hopper. From there it is fed continuously into a Hydrapulper. The pulping action of the pulping rotor reduces the frangible material to sufficient size to pass through 1/2" holes of an extraction plate located beneath the rotor. The heavy inorganic materials are removed by a bucket elevator, called a junk remover. The pulped material passes through a liquid cyclone to separate heavy materials, such as dirt, broken glass, small bits of metal, bone, etc. The remaining organic material passes to a series of screens which progressively concentrate the paper fiber. One of the screening operations removes the fine fiber and ground food waste from the more valuable and easier draining long fiber. Residual heavy dirt and odd-shaped particles of organic material are removed from the long fraction with centrifugal cleaners. From the cleaning step the paper fiber is thickened for transport to a nearby mill. Depending on the desired end product, the fiber may be given further purification by chemical treatment in the customer's mill to dissolve small particles of vegetable matter (leaves, grass. wood, etc.)."

The company believes that much of the glass content of the refuse can be recovered. The organic material rejected from the process is in the form suitable for composting but in the Franklin installation this will be incinerated in a fluid bed reactor.

## CAPITAL AND OPERATING COSTS

The capital and operating data cannot be readily estimated but the company has published the information given in Table 7.1.

TABLE 7.1: OPERATING DATA FOR A FIBRECLAIM UNIT

| ITEM | CAPACITY TON/DAY | |
|---|---|---|
| | 50 | 1000 |
| Operating hours per day | 8 | - |
| Products: Paper Fibre, T/Day | 10 | 200 |
| Ferrous Metals, T/Day | 4 | 80 |
| Glass Cullet, T/Day | 4 | 80 |
| Aluminum, T/Day | 0 | 10 |
| Steam, lbs/hr | 0 | 150,000 |
| Capital Cost, million $ | 1.74 | 8.50 |
| Net Est. Operating Cost $/ton | 4.50 | < 2.50 |
| Unit Capital Cost $/ton day | 34,800 | 8,500 |

It is understood that a figure of $25 per ton has been used in estimating the income from recovered paper fibre but no information is available to indicate the value of the other products assumed in estimating the net cost of treatment. If the full scale unit is found to operate in a similar fashion to the pilot plant it would appear that further refining processes may be needed to provide a saleable product for the recovered metal, glass and aluminum fractions.

DISCUSSION

This process has aroused widespread interest. Physical recovery of some of the more valuable constituents of refuse is accomplished without a manual salvaging operation. The process is continuous and has all the more pleasant aspects of a pulping and refining plant in contrast to those normally associated with a garbage disposal unit. The operating data and experience to be obtained from the Franklin plant unit is needed, however, to evaluate the practical feasability of this process.

In predicting the future of this process, the promising features must be balanced against the inherent weaknesses of the process which appear to be as follows:

1. The waste is pulped and separated in water which is recirculated. The health hazards involved to the operators and the pollution problems created by the surplus water from

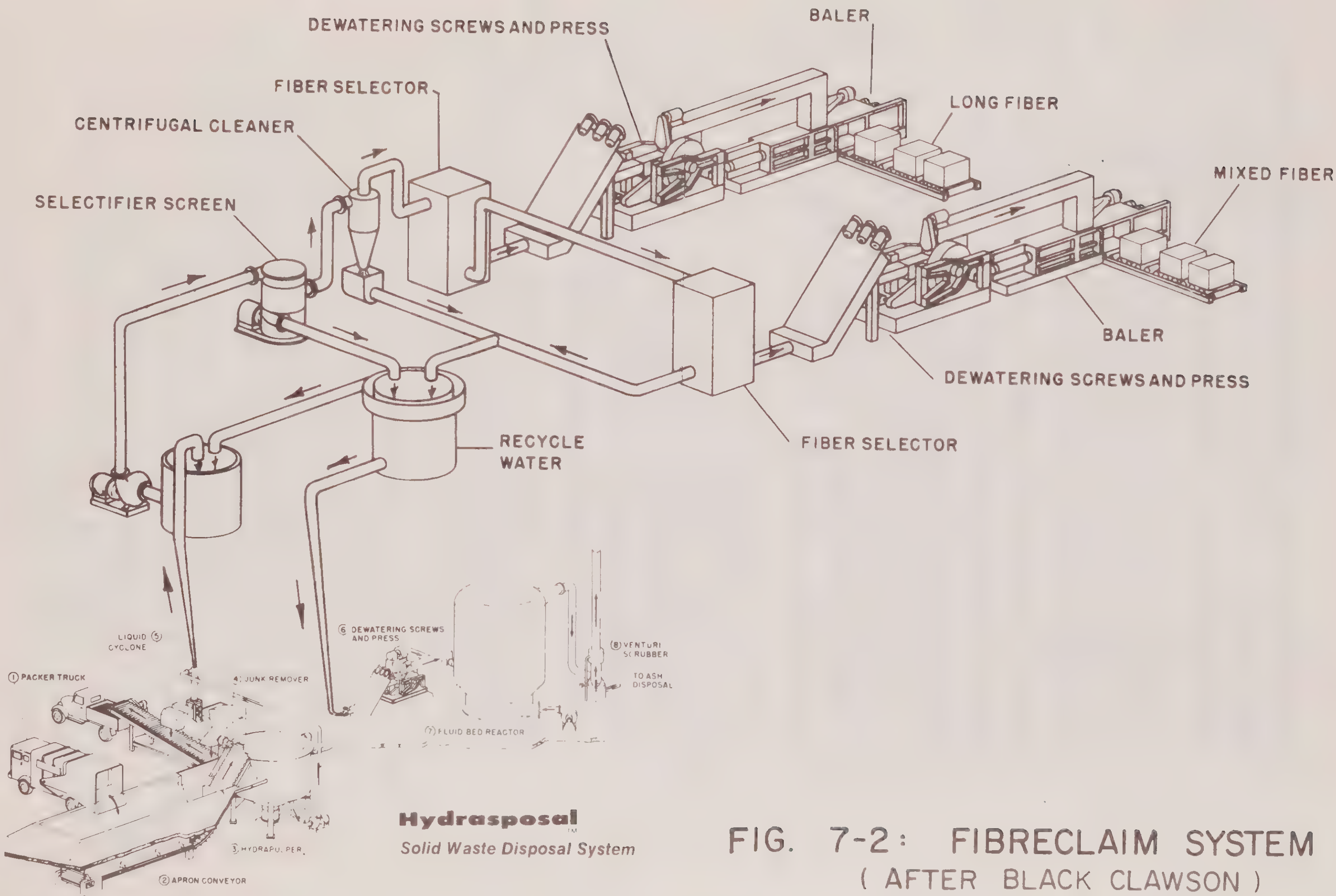



FIG. 7-2: FIBRECLAIM SYSTEM
( AFTER BLACK CLAWSON )

the plant will need to be carefully investigated and perhaps controlled.

2. Basic to the process is the concept of disintegrating and mixing all materials prior to the separation stages. This undoubtedly complicates the separation process and as the company admits even the paper product might have to be "chemically refined to dissolve small particles of vegetable matter". In future, the products of this process might be regarded as unsatisfactory in competition with cleaner fractions obtained by another method of reclamation.
3. It is surprising to realize that only 40 percent of the paper originally in the refuse is reclaimed by this process. One is forced to consider whether the capital expended to this end would be wisely employed if a significant fraction could be salvaged by hand or could be separately collected from the community in the clean state.
4. The unit capital cost per ton per day of a Fibreclaim plant is higher than that for any other waste treatment operation, on the same tonnage basis. Communities may well find difficulty in raising the capital required for this process and caution should be used in assessing the reported operating costs, since these will be considerably modified by the method and costs of financing the initial capital investment.

## HYDROLYSIS

Cellulose can be hydrolysed using sulphuric acid to produce sugars which in turn can be fermented to provide alcohol. The conversion of waste cellulosic materials into alcohol by this route has been investigated by a number of research teams including those at the Saskatchewan Research Council, National Research Council and the Ontario Research Foundation. It was concluded that the various processes were feasible but not sufficiently attractive economically to warrant a commercial operation.

Recently, this process has been advocated by A. Porteous for

the treatment of garbage, which contains a high proportion of cellulosic materials. Using a high temperature hydrolysis process at 446 °F the hydrolysis time is stated to be reduced to 72 seconds and greater yields are said to result[1].

The process involves the preliminary preparation of the waste fraction for hydrolysis and glass, metals and large items of trash are first removed from the municipal waste. From the enriched cellulose fraction, consisting mainly of paper, a conversion of 0.3 tons of alcohol is obtained from one ton of cellulose. A plant to treat 250 tons of waste per day is estimated to cost £1.3 million sterling but is said to provide a profit of almost £1 sterling per ton of refuse containing 40 percent paper. The total sale of ethanol from such plants is estimated to be such that the price of alcohol will not be deflated and the current price of £6 sterling per ton is assumed to hold.

On a straight conversion basis these figures are equivalent to a capital cost of $3,250,000 and a unit cost per ton day of $17,000. Further data is required to evaluate the operating costs and revenues to be obtained in Canada but it is conceivable that in spite of the high unit cost this process could be of value to some of the larger communities.

This process is in the development stage and the method of primary separation and the disposal of liquid wastes from the hydrolysis and fermentation stages need careful attention. It would also appear that this might only be a limited solution to the problem of waste disposal and that the process might have an uncertain future in view of the cheaper and more easily handled raw materials which are available for the production of alcohol.

1. Lenihan, J. "Turning Rubbish Into Alcohol" Engineering Digest, August 1970. p. 60

# COMPACTION

A compaction operation could be of importance in the collection, transport and disposal of domestic and municipal wastes.

A useful degree of compaction is already obtained in many designs of collection vehicles in which the bulk density of the material is increased, on average, from 8 to 16 lb per cu ft. Presumably the extra cost of these special vehicles is offset by reduced transportation charges but, with the introduction of domestic and commercial presses, this situation might need future review.

The effect of the degree of compaction on the cost of a landfill operation has already been stressed. Further attention should be given to the value of mobile compacting equipment such as the Michigan Trash-Pak[1] which can exert a crushing force of 1061 pounds per linear inch, sufficient to smash stoves, refrigerators and the toughest refuse during the landfill operation. Other mobile landfill machinery for trenching, baling and covering in one operation could also provide higher compaction densities than now achieved. This type of mobile compaction equipment requires a more thorough study than can be given in the present report since many of the advantages claimed for the prior pulverization of refuse could possibly be achieved for smaller communities with this simpler equipment.

Recently the Japanese process that compresses garbage into odour-free steel clad blocks has aroused wide interest. This is a high compression process which increases the bulk density of the waste to 70 to 100 pounds per cu ft. Rogus[2] concludes after a detailed examination of this sytem that

> "The application of high compression baling systems to American usage is feasible, should simplify and enhance long distance hauling and substantially reduce the operational nuisances and potential hazards of sanitary landfill."

The combination of a pulverization operation with a compaction process has also been proposed by S.F.M. Corp., Union, N.J.

1. Lucken, Ben "Communities Jointly Solve Refuse Problem", Public Works. Oct. 1968 p. 156

2. Rogus, C.A. "High Compression Baling of Solid Wastes". Public Works, June 1969. p. 85-90.

Compaction is an important unit operation in solid waste management practices, but in keeping with the scope of the report, only a brief review of the technical problems can be given. The reader is referred to the report entitled "Solid Waste Processing" for a more comprehensive account[1].

The pressures required for compaction are determined by the degree of compaction required and by the nature of material and by the particle size and moisture content of the individual constituents. The effect of differences in waste composition is illustrated by Figure 7.3 which provides a comparison of data obtained at Chandler, Arizona, and London, England. Of equal importance is the final density achieved upon release of the compressive force, but this data appears to be completely absent in the literature. Unfortunately, the literature contains very little basic information of this nature and experimental tests for an individual case are needed in order to assess properly the virtues of a compaction operation.

The Chandler data for bulk density as a function of initial bulk density and compressive force is given in Figure 7.4. In the high compression range, the bulk density achieved is independent of the initial bulk density and for a 100 p.s.i. compressive force a bulk density of 52 lb per cu ft is obtained. Extrapolation above these values is not justified but it would appear that for the material used in these tests even higher bulk densities could be reached before a point of diminishing returns is attained.

The data reported for the Japanese Tezuka-Kosan compression process indicates that bulk densities in the range of 70 to 100 with an average of 88 pounds per cubic foot can be obtained using pressures of approximately 5,200 p.s.i. Although this data will not be directly applicable to Canadian conditions, it would seem that unless an ultimate use for the steel clad compressed blocks is foreseen, compression to this degree may not be justified to reduce the cost of transport or the cost of a landfill operation.

1 "Solid Waste Processing", U.S. Dept. of Health, Education and Welfare, P.H.S. Publication No. 1856.

The required degree of compression, the form of baling and the costs of a compaction operation for Canadian conditions need to be determined before overall cost estimates can be made. It would appear that insufficient attention has been given to this method of disposal, and although the only attempt to use this method on this continent was unsuccessful, a further investigation should be encouraged for the following reasons:

1. The baling process in the medium pressure range is a relatively simple mechanical operation and capital and operating costs could be lower than those for pulverization.
2. The bales could be handled, transported and placed on a disposal site using standard materials handling equipment.
3. The baled material, if used in landfill operation, would provide all the nuisance-free characteristics of a pulverized material and in addition could be less unsightly.
4. The construction of recreational hills or land features would be facilitated and might find greater public acceptance.
5. The smaller landfill site area required would allow for better control of the leachate and its treatment, particularly if artificial hills could be constructed.
6. For most Canadian communities, especially in the North, any simplification of the all-weather landfill operation merits attention.

## OTHER METHODS

With the intensity of effort now being directed toward the solution of solid waste disposal problems in the U.S.A. and Europe, new processes, equipment and combinations of processes will be evolved more rapidly than in the past. Reports on the state of the art now have a very limited useful lifetime and a continuous review of the literature is essential to maintain a perspective on possible future developments which might influence immediate decisions and future plans for waste treatment.

In this connection chemical processing of waste materials to

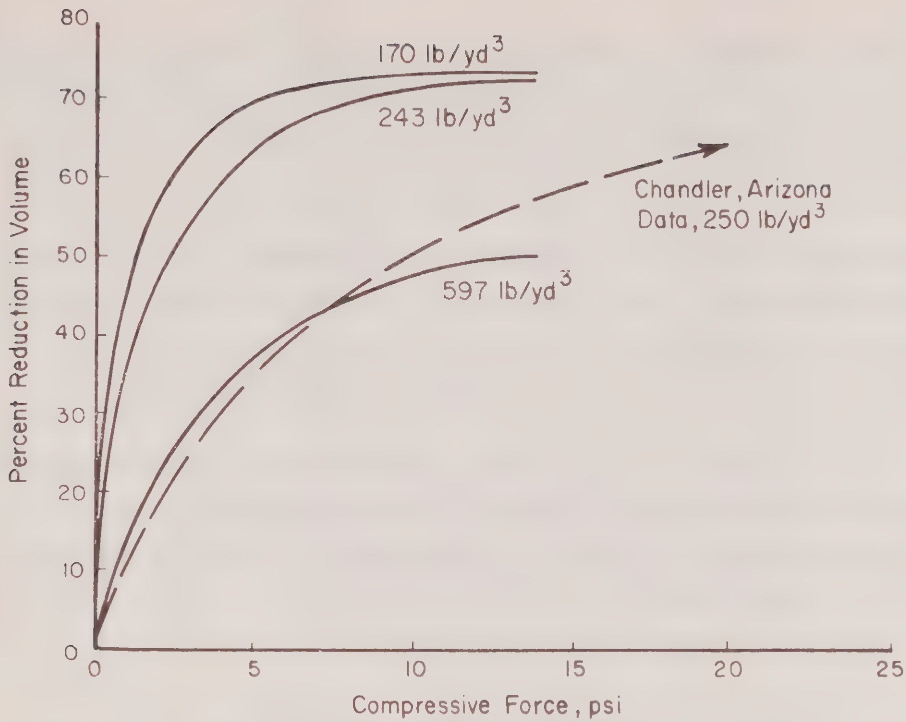



FIGURE 7.3: EFFECTS OF COMPOSITION ON COMPACTION ACHIEVED
(After P.H.S. Publication 1856)

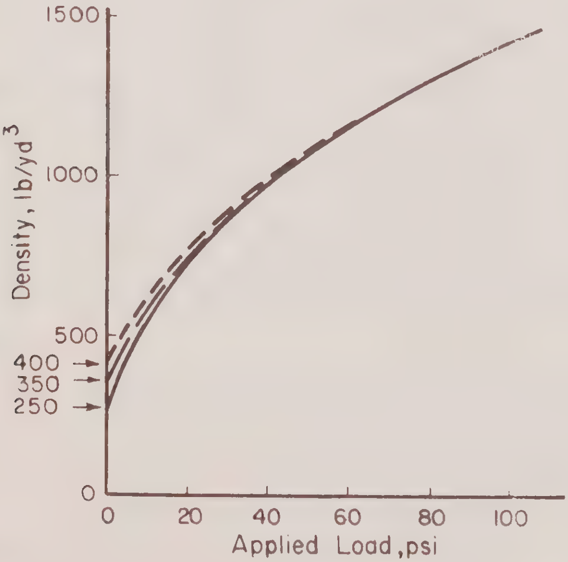



FIGURE 7.4: BULK DENSITIES ACHIEVED BY COMPACTION
(After P.H.S. Publication 1856)

produce new materials could assume far greater importance. The high temperature, high pressure reaction of refuse with carbon monoxide to produce hydrocarbons might be found to be economically attractive. Wet oxidation of waste at high pressures and temperatures is now being investigated which could lead to an integrated sewage and solid waste treatment process. Controlled thermonuclear fusion to vaporize the waste into its basic elements and the recombination of these to produce new materials has also been proposed. Of even greater significance perhaps are the attempts to convert waste into edible materials.

New ideas, such as these, deserve financial support for their research and development so that solutions may be prepared for the future problem of satisfying the demands of an increased population in the face of dwindling natural resources.

# CHAPTER 8

## RECLAMATION SYSTEMS

In the previous chapters, the emphasis has been placed on the methods of waste disposal. With the exception of those concerned with landfill and the preparation of the waste for this operation, all the methods permit some degree of reclamation either in terms of energy, products of chemical reaction or, as in the case of composting, in terms of new potentially useful products. Little attention has so far been devoted in this study to reclamation of significant quantities of materials in their original physical form. Although a salvaging operation could be part of some of the processes previously considered, salvage would not aim to recover the quantities sought in reclamation processes.

The U.S. Bureau of Mines has investigated the possibility of recovering materials from incinerator residues. It is reported[1] that these contain approximately 50 percent glass and 30 percent metallics and in this enriched form their separation to provide additional revenues offers attractive possibilities. Preliminary estimates for the primary separation of glass and metal indicate a cost of approximately $3.50 per ton of residue but further refining steps would then be necessary. The development of an economic process would serve to reduce the costs of incineration and if the residues were to be transported for treatment to a central processing plant incineration units could become a viable alternative for small communities.

A pyrolysis process could also involve reclamation of material if a sorting operation is included in the segregation of the waste prior to the operation. Other methods of treatment involving bio-chemical and chemical treatment and high temperature reactions might also profitably include a reclamation stage.

The process of composting has historically been associated

1. Anon, "Wealth Out of Waste" Nation's Cities, Sept. 1969

with reclamation. Opportunities for reclamation are presented prior to the composting operation in the course of preparing the raw waste and at a subsequent stage in which the compost is refined to improve its saleability and characteristics. Most of the compost units now in operation include equipment for salvaging materials and the revenue obtained from this operation often effectively reduces the overall treatment cost.

One of the most comprehensive reclamation systems installed on this continent was operated by the General Conversions System Corporation at San Fernando, California. In this unit a Naturizer-type composter was employed in conjunction with a Salvage and Conversion Systems unit designed by Lockheed for the corporation. A flowsheet for the SACS process is given in Figure 8.1[1]. The designed capacity of the San Fernando plant was 150 tons per day of unsorted refuse and units of this size were estimated to cost between $1.4 to $2.2 million dollars. For the designed capacity only 15 personnel were stated to be required .

More recently, the Metropolitan Waste Conversion Corporation at Houston has developed its salvage operations in conjunction with its composting unit. Markets for paper and metals have been established and new methods for the extraction of glass are being developed .

These are merely two examples of reclamation processes which are being operated in many parts of the world. A number of these units, particularly in the U.S.A., have failed, however, because overly optimistic estimates have been made for the markets and prices of salvaged materials. Although overall profits should not be expected from a municipal waste disposal operation, reclamation affords a means to reduce the costs of disposal by providing a revenue and by reducing the quantity of material to be processed. Reclamation also reduces the hazards of pollution from waste disposal operations and serves the cause of conservation by recycling materials back for industrial processing or direct re-use as substitutes for more

1. "Solid Waste Processing", U.S. Dept. of Health, Education and Welfare. P.H.S. Publication No. 1856.

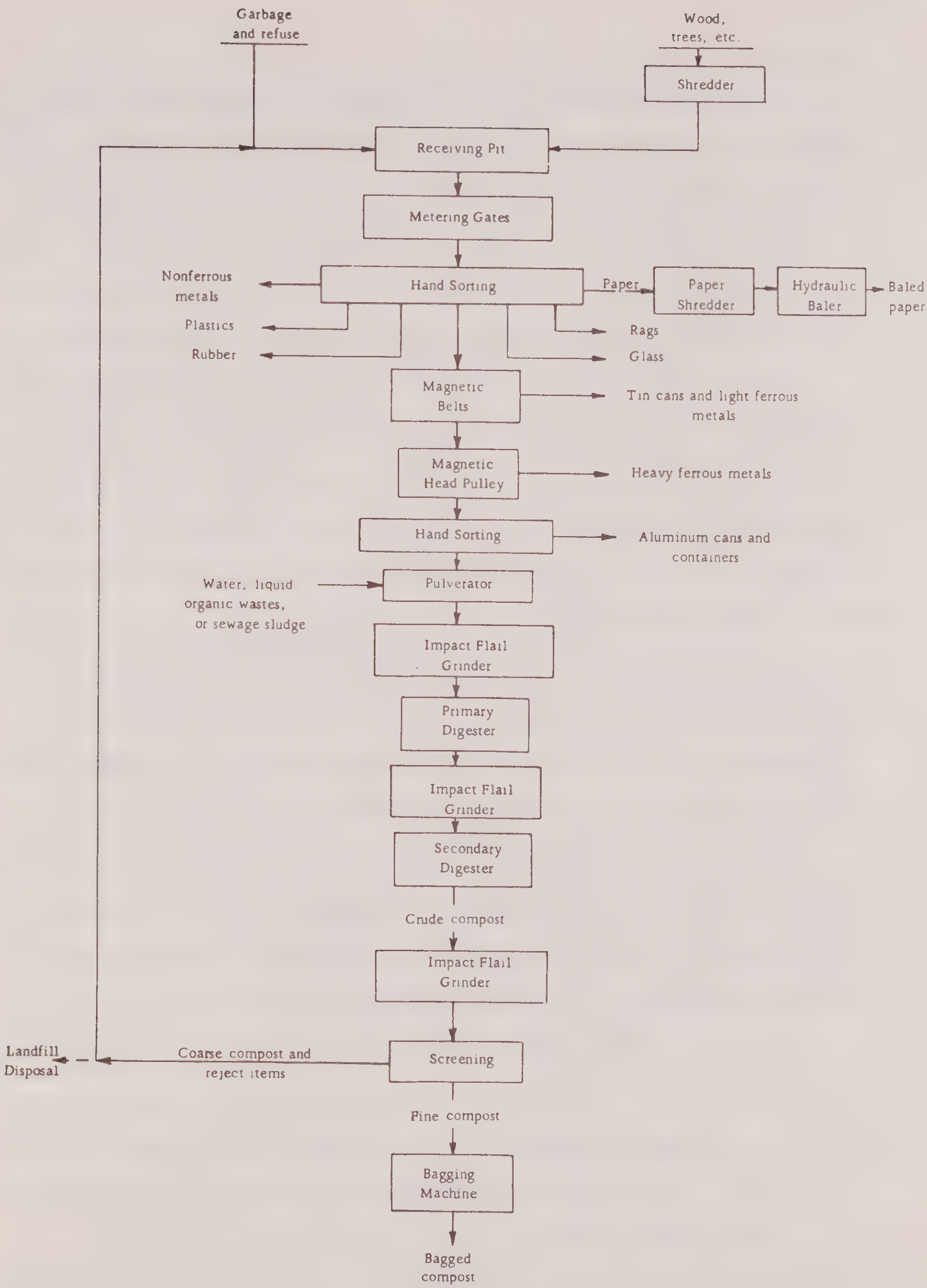



FIGURE 8.1: FLOWSHEET FOR SACS PROCESS
(After P.H.S. Publication No. 1856)

valuable materials.

In this chapter the feasibility of a reclamation system for Canadian conditions will be investigated in detail since the authors believe that physical reclamation will be an essential component of many future disposal systems. Furthermore the integration of a reclamation system with a means for treatment of all organic wastes would appear to hold great promise as a suitable solution for the waste disposal problems of the smaller communities in Canada.

The separation of materials is not a new problem for the engineer and there is a wealth of knowledge and specialized equipment available for this purpose. The task is therefore to choose the most appropriate equipment and to devise a process which will suit the immediate conditions and provide sufficient flexibility to allow for future changes in the quantity and type of waste and in the markets for recovered materials.

The first unit of this kind in Canada has to be designed without the benefit of any operating experience under Canadian conditions and, being the first, it must provide a convincing demonstration of the feasibility of the process. For these reasons only standard items of equipment commonly found in the mineral industry will be chosen and reliance will be placed on manual separation for the more complex sorting operations. The capital costs of the equipment may therefore be compared to those for mineral beneficiation operations, whereas the operating charges will be highly dependent on the labour employed for sorting.

It is self-evident that partially mixed materials are more easily separated than those which have been ground or intimately mixed. The process of reclamation should therefore start at the source of these wastes and segregation of the constituents should be attempted. The degree to which this is pursued to reduce the costs of reclamation is related to the additional costs of collection which might be incurred. The nature of this problem is being investigated by the City of Madison and the American Paper Institute and it is reported, for example, that the separate collection of newspaper for shipment to paper mills does not appear to be economically feasible[1]. Whether or

1. Abrahams, John H. Jr., "Packaging Industry Looks At Waste Utilization", Compost Science, Vol. 10, No. 1-2.

not a deliberate attempt is made to segregate materials, a certain degree of segregation is naturally obtained due to the variation in composition of different loads collected from domestic and commercial sources and a good reclamation system should be so designed as to take full advantage of these differences in the feed composition.

The putrescible waste fraction should be segregated if at all possible. This consists of waste food and other organic wastes which could constitute a health hazard together with other refuse which has been contaminated with these materials. In most areas domestic garbage constitutes the major part of this putrescible fraction and the virtues of separate collection have been recognized by many communities. Apart from assisting a reclamation operation and reducing the health hazards, separate collection of the putrescible fraction might reduce the costs of collection since less frequent collections could be instituted for the remaining wastes. A New York study[1] reports that with bi-weekly collections, separate collection increases the collection costs by approximately 30 percent. But it can also be seen from that study that if the collection is reduced to once per week, with separate collection of the putrescibles, the collection costs might be reduced by about 30 percent from those for bi-weekly collections of the combined wastes.

An examination of collection procedures is not within the scope of this report but it is clear that the benefits of a segregated collection system should be explored in evaluating a reclamation process. For this reason, the reclamation of materials from segregated and unsegregated waste is independently considered.

## BACKGROUND INFORMATION

The overall composition of the waste and the composition of the commercial fraction is required for this analysis.

The approximate composition of domestic waste can be estimated from Table 2.2 but the composition of the commercial portion of the municipal waste is more difficult to determine since much depends on the nature and size of the community. However some estimate of this is required in order to proceed with the evaluation

1. "Municipal Refuse Collection and Disposal". Office for Local Government, State of New York, Sept. 1964, p. 14

and at this stage the following assumptions would appear to be reasonable:

1. Commercial wastes will contain the same proportion of cardboard as domestic wastes.
2. The proportion of garbage arising from restaurants, food distribution businesses, waste receptacles and entertainment centres is equivalent to that found in domestic waste.
3. The proportion of clean recoverable paper from offices, retail and wholesale stores and from industries will be approximately equivalent to the newspaper fraction in domestic waste.
4. Commercial waste will contain the same proportion of metals, glass and plastics as domestic waste although the physical form of these materials might be different.

In effect these assumptions provide for a commercial waste fraction analysis identical with that for domestic waste. This condition will only be valid if the commercial fraction does not include industrial wastes, waste vegetation or large quantities of demolition and building materials but those conditions seem reasonable.

The assessment of commercial waste as being identical in general composition with domestic waste leads to a conservative estimate of the reclamation revenue. More cardboard, metals, wood and vegetation material such as leaves and grass trimmings could make the reclamation process more profitable. The inclusion of industrial wastes could also have the same influence by virtue of their composition or the revenues which could be obtained for their acceptance by the municipality.

The recovery of materials and their market value is considered in Chapter 9. Approximate estimates of the quantity of material separated and recovered have been made for the processes described in this chapter and are reported in Table 8.1.

It will be noted that in the absence of actual operating data minimal recoveries of saleable products have been assumed. For example, with a segregated collection system more than 80 percent of the newspaper content should be recovered and at least a fraction of

TABLE 8.1: PRODUCTS FROM RECLAMATION SYSTEMS
(Basis 100 lb Dry Municipal Refuse)

| MATERIAL | ORIGINALLY PRESENT lbs | MATERIAL RECOVERED & PRODUCTS | | | |
|---|---|---|---|---|---|
| | | SEGREGATED FEED | | UNSEGREGATED FEED | |
| | | lbs | % of original | lbs | % of original |
| Metal | 8.3 | 6.0 | 72 | 6.0 | 72 |
| Cloth | 3.6 | - | - | - | - |
| Plastics | 3.1 | - | - | - | - |
| Rubber | 1.0 | - | - | - | - |
| Glass | 8.3 | 6.0 | 72 | 3.0 | 36 |
| Wood | 2.0 | 1.0 | 50 | 1.0 | 50 |
| Garbage | 15.5 | - | - | - | - |
| Newspaper | 9.75 | 8.0 | 82 | - | - |
| Cardboard | 24.0 | 16.0 | 66 | 12.0 | 50 |
| Other Paper | 19.25 | - | - | - | - |
| Compost | - | 40.0 | - | 50.0 | - |
| Inerts | 5.2 | 7.0 | - | 7.0 | - |
| Composter Gas | - | 16.0 | - | 21.0 | - |
| TOTAL | 100.0 | 100.0 | - | 100.0 | - |

this material could be extracted from an unsegregated feed. However the recovered amount for this analysis, as indicated in Table 8.1, are only 82 and 0 percent respectively. Furthermore it is assumed that cloth, plastics and rubber and special papers will not be recovered and that they will leave the system as inert material or will be degraded in the composting unit.

Of the materials recovered only a fraction will find a suitable market. It is anticipated that the inert fraction, consisting of coarse and fine refuse, will be buried as inert landfill material. It is conceivable that as clean fill this stream could be readily employed in a community and the reclamation unit should only be charged with the costs of transportation to the site. However a charge of $3.00 per ton has been included in the estimates for the disposal of this material.

Markets for cardboard, newsprint and glass do exist and the figures given in Chapter 9 provide an indication. Only one sixth of the metal recovered has been assumed to be directly saleable at the present time. Thus for the saleable metal fraction consisting of aluminum and copper neither charge or credit has been applied and the remainder of the recovered metal fraction has been valued at only 50 cents per ton. The sale of scrap wood has only been assumed to cover the cost of the disposal of the unsold fraction. The sale of cardboard, newsprint and glass has been evaluated using the data given in Chapter 9.

The amount of compost produced far exceeds any other product in terms of quantity. Since a market for this material has not been established it will be assumed that ten percent of this will be sold to the citizens of the community at a price to cover the handling charge, if any. It will be assumed that the remainder will be trucked to an area outside the city at a cost of $1.00 per ton and dumped on unused fields, swamps or bushland to upgrade these areas or to provide a future source of humus and top soil.

In addition to these conservative assumptions relating to the revenue from reclaimed products the following assumptions will be made:

1. The plant will be municipally owned and operated and amortization charges will accordingly be estimated on a 20 year basis with a bond interest of 9-1/4 percent. Land taxes will be

omitted from the estimates.

2. The waste feed will be delivered to the plant without charge to the operation.
3. Operating labour charges will be estimated at $3.50 per man hour.
4. Overhead charges for operating labour will be estimated at 40 percent of the direct labour charges. An additional overhead charge for supervision and marketing will be included based on plant size and anticipated sales.

These assumptions are in keeping with those used in estimating the costs of other disposal operations to insure the validity of direct comparisons of all the estimates given in this study.

## RECLAMATION FROM A 'SEGREGATED' WASTE

It will be presumed that the fraction containing food wastes, soiled paper products, wet wrapping material and plastic wrapping, but excluding food cans and bottles, will be separately collected and treated.

Public acceptance of this approach is not considered to be a serious factor in its adoption. Already, many households separate the garbage fractions as a matter of convenience within the household. The enforcement of the necessary by-law might, in the first instance, be left as the responsibility of the collector who could be instructed not to collect paper and trash which has been contaminated with putrescible material. Few citizens would be willing to criticize his discretion. Although the operation of a separate collection system could decrease the cost of collection it will be assumed that the reclamation system would have to carry an increased collection charge of $1 per ton.

The process recommended for the reclamation of segregated wastes is illustrated in Figure 8.2. It will be noted that two receiving areas have been provided, one for the putrescible fraction and the other for the remaining wastes which will be partially reclaimed. If the waste from the two sources could be delivered in a suitable programmed sequence these two receiving units could be

combined to provide a reduction in plant size and capital investment.

The putrescible fraction is fed to a cage mill and the moisture content of the ground product is then adjusted by the addition of water or sewage sludge. The resulting pulp is sent to the aerobic digester and the crude compost from the digester is conveyed to a stockpile using either a truck or belt conveyer.

The other wastes received are checked for acceptability. Material which is grossly oversize, and clean fill, is sent directly to a disposal site but the major portion of the material is fed to the sorting conveyer from which saleable products are salvaged manually. After the primary salvaging operation the larger objects are mechanically removed from this stream and rejected from the process as material suitable for clean fill. The remaining material is then sent to a screen to remove the fines which are conveyed to the cage mill as material suitable for compost production. The oversize fraction from the screen will include bottles, cans, plastic containers and some paper products. This material is crushed to flatten cans and to break the glass; the ferrous content is extracted using magnetic separators and the product is once more screened to remove the crushed glass. The product from this step is then separated into metallic, paper and plastic fractions by an air separation system.

No allowance has been made for equipment to refine or to prepare the reclaimed materials to provide the most desirable form for transport or marketing. Instead additional labour has been included to undertake this preparation in the simplest manner to meet the lowest standards acceptable for sale. The development of refining techniques merits a separate study once the markets have been established since the cost of any improvement in product quality must be matched by increased revenues. For the purposes of the study the lowest prices for unrefined materials will be used to estimate revenues.

A more detailed description of the various units is required in order to appreciate their function, the nature of the equipment and the problems to be solved in the final engineering design.

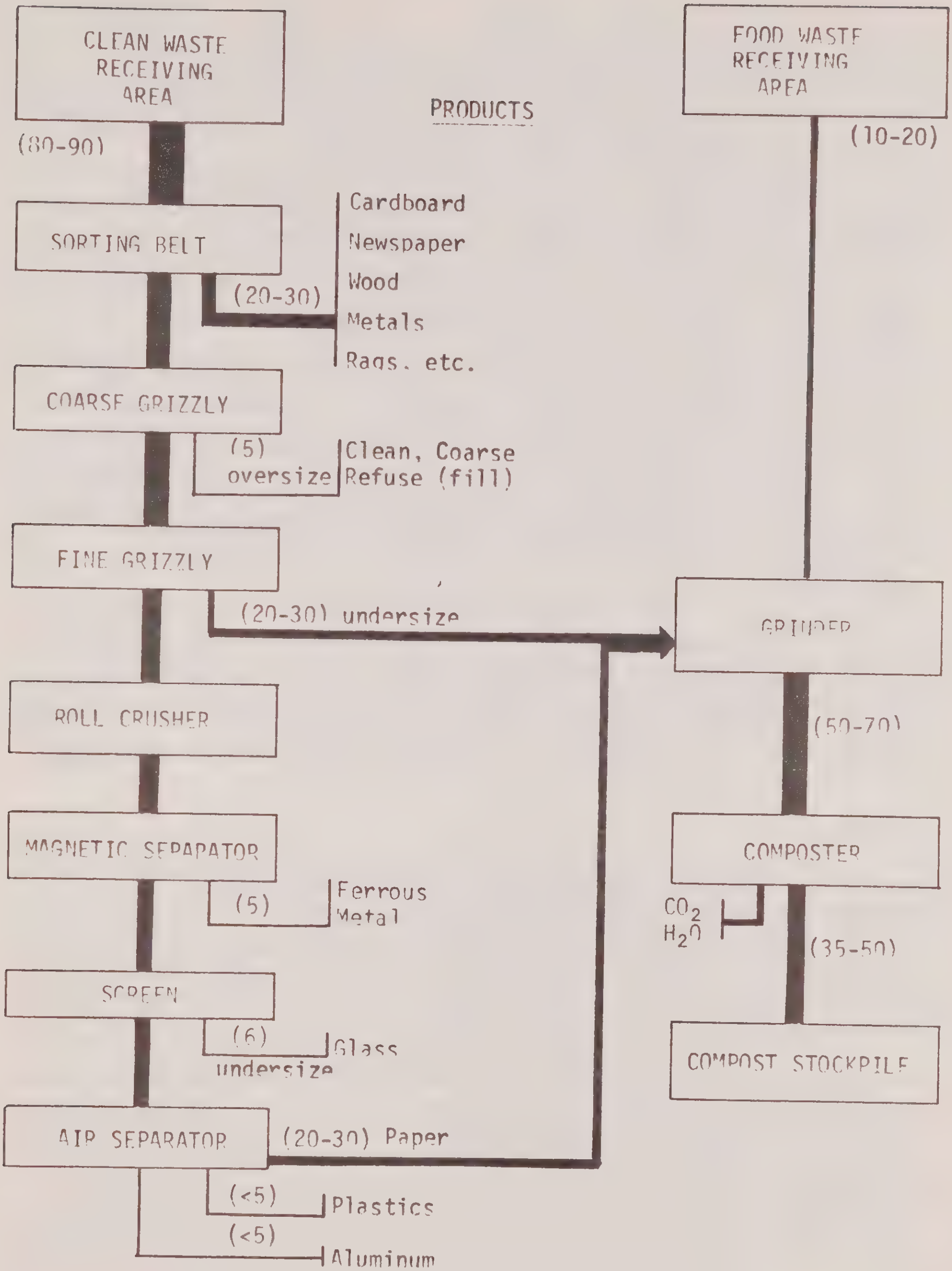



FIGURE 8.2: RECLAMATION PROCESS FOR SEGREGATED WASTES (Bracketed numbers indicate percent of total feed in stream).

## RECEIVING AREA AND FEEDING EQUIPMENT

This part of the system has to be designed to permit the immediate discharge of refuse vehicles and provide a continuous and uniform flow of material to the reclamation units.

Municipal waste is by no means a free flowing material and individual constituents can cause considerable problems in poorly designed handling systems. In the larger units the live bottom hopper system has proved to be the most satisfactory system, but although the length of the hopper can be reduced to allow for smaller capacities the width of the hopper and conveyer must be maintained. The costs of this system therefore become relatively more expensive as the capacity of the reclamation unit is decreased. For systems of small capacity the combination of a flat concrete unloading pad and end loader to feed a narrow width conveyer has been found to be satisfactory.

This is a unit which requires further study and development but for the purposes of the present study it will be assumed that end loader operation will be used for capacities up to 50 tons per day and that above this capacity a live bottom hopper will be employed.

## CAGE MILL

The cage mill pulverizes all the putrescible fraction which is fed directly to this unit together with the fines from the reclamation process. Water or sewage sludge is added at this point to provide a satisfactory moisture content for the composting operation. The pH of the mixture also can be adjusted if necessary.

The size of this mill and its power requirements are in keeping with the nature of the feed and its quantity. It is estimated that 50 to 70 percent of the total municipal waste will be pulverized and composted. Since the feed to the mill should be relatively free from metals, glass, wood and heavy bundles of paper the power requirements and maintenance will be greatly reduced per unit weight of feed material in comparison with that required for pulverization of the total waste (see Chapter 4).

## THE COMPOSTING SYSTEM

Although many designs of composter could be employed, the Fairfield-Hardy composter has been previously chosen in this study for the purpose of cost estimation. This unit which is described in Chapter 6 has been selected, therefore, for evaluating the economics of the reclamation process. Mechanical composting units of this kind are remarkably tolerant of variations in feed composition and feed rate and very few operation problems are to be anticipated.

The crude compost product will contain strips of plastic bags and small amounts of glass, metal and plastics as the most recognizable refuse constitutents. This material could be separated but in the absence of a developed market for compost this refining operation will not be included in the cost estimation. The crude compost will, therefore, be stockpiled outside the plant for local use. It should be noted that no hazards are invited by this decision. The composting process destroys pathogenic organisms and kills seeds, and the crude compost is similar in appearance and properties to peat moss. It can be recovered from the stockpile throughout the year since rain-water does not penetrate the mass and material does not freeze below the surface layer.

## THE SORTING BELT

Sorting belts are common elements of waste disposal plants and their function is to permit the manual extraction of the most valuable and the most readily removable constitutents of the refuse. The sorting operation envisaged in this process does not require the sorter to handle any unclean, objectionable or heavy items of refuse. It should also be remembered that with a segregated collection system the putrescible fraction will be small and therefore this operation should be relatively clean and pleasant in comparison with similar operations in which unsegregated material is sorted. The operating conditions can be made more pleasant by suitably designing the ventilation and lighting systems.

It is especially important to understand that the sorting operation does not require sorters to handle objectionable items

because the sorting belt automatically conveys materials not removed by a sorter to the next process step. Sorters only remove from the belt those items that can be removed safely and beneficially.

The aim of the sorting process is to recover directly those materials which are valuable in the form in which they are collected, such as cardboard, newspapers, and identifiable ferrous or non-ferrous metals. In addition, wood, mostly from packing cases, would be removed and, if the quantity and the market justify it, rags might also be extracted.

The sorting belt provides a flexibility in the recovery of values that no mechanical device can duplicate. Clearly this benefit carries with it a high labour cost but no machine has been devised to perform the same task or to provide the degree of flexibility which is required initially to exploit the varying and, at this time, the largely unexplored markets for reclaimed material.

MECHANICAL SEPARATION SYSTEM

Oversize Separation: This step is introduced to permit the removal of such large objects as old tires, bundles of brush, large cans and blocks of wood. These items rarely have value but they complicate and menace the capacities needed for subsequent treatments. Therefore a simple but effective separation is required. The estimates are based on use of a vibrating grizzly screen with 6-inch bar spacing which should prove to be very satisfactory for this purpose.

It would be reasonable at this point to provide for the handling of brush. A man stationed at the grizzly, either at the head of it or at the oversize discharge point, could pull brush out of the flow and feed it into a chopper. The product could then be directed to the composter, or elsewhere as required. However this would be an optional refinement in the process and has not been included in equipment or operating cost estimates.

Fine Sizing: It is desirable to remove fine materials from the non-magnetic stream so that a clean glass product can be obtained after this stream is crushed. A vibrating grizzly with 2-inch bar spacing

has been chosen for this purpose. With this device, most wood chips and debris should be removed without the loss of a significant quantity of glass, metal or plastic. Note, for example, the diameter of a soft drink can is about 2-1/2 inches and of a baby food jar also about 2-1/2 inches; only small bottles, paper scrap, broken glass, and bottle caps are likely to pass through the screen. At the same time it is not essential that all such material be removed at this point since any carryover will be extracted after the crushing operation.

Crusher: The function of the crusher at this stage of the process is to break glass to pieces finer than one inch in size without pulverizing cans, plastics or paper to any marked degree. Fortunately this can be achieved readily in any one of several devices. A cage mill, a hammer mill without a screen, or a set of rolls will all be effective. Rolls will minimize breakage of materials other than glass, though they may not ensure the breakage of sheet glass. To some extent, the impact mills will tear paper and possibly metals though at low speeds either device should prove acceptable. On balance, rolls should provide the best solution since the glass will not be totally pulverized in this type of equipment and the subsequent separation of glass into coloured and clear stream, if desired, can then be achieved with standard equipment. It is therefore assumed for the purpose of this estimation that a set of corrugated crushing rolls will be used.

Magnetic Separator: It is inevitable that some cans and bottles will pass through the fine grizzly and the presence of some of these must be assumed in the feed to the cage mill. However these will be a small part of the total flow and should not have a significant effect on that mill. If more or most cans must be separated ahead of the cage mill it will be quite practical to insert a magnetic head pulley in the transfer conveyor and glass can be separated after composting, if necessary.

The major portion of the magnetic material will be in the form of cans in the fine grizzly oversize fraction. These will be flattened in the roll crusher and a magnetic separator, either an

overhead belt unit or a magnetic head pulley, will be installed in the conveyor feeding the glass screen. A major role for this separator will be removal of small pieces of ferrous metals, such as bottle caps which could contaminate the glass produced, and a magnetic head pulley would appear to be the preferred device for this separation.

Glass Screen: This unit merely separates broken glass from the coarser unbroken metals. The glass product may contain paper and plastics without loss of value and all-aluminum containers will be rejected by proper selection of screen cloth; probably a one-inch square opening will do, though a slotted cloth may also be effective.

The screen oversize will consist for the most part of flattened aluminum, scrap copper, paper, plastic containers and bits of wood. This stream should be treated to recover aluminum at least and there should be no problem in doing this by density separation. However in the absence of definite knowledge of the amount of material involved it is assumed that the stream will be disposed of at no cost and with no return. Probably no assumption more conservative than this is made in this report since aluminum has a high scrap value.

## DISCUSSION

The estimated costs for this process are given in Table 8.2 together with the numbers of operating personnel required for each plant size. In addition, a breakdown of the operating costs and the distribution of manpower in the 50,000 ton per year plant is reported in Table 8.3.

The data shows clearly the effects of the design requirements and expected effect of scale. The design requirement that the same form of voluminous material must be handled at all plant sizes is indicated by the figures for the capital investment. For plants up to 50,000 tons per year in capacity a single composter unit is required and it will be noted that the costs for the 100,000 ton per year plant reflect the inclusion of a second composter. Depending on the amount of paper recovered, the additional unit may or may not be required.

Operating costs are dominated by salaries and wages as the

TABLE 8.2: COST ESTIMATES FOR A RECLAMATION PROCESS WITH FOOD WASTE SEGREGATION

| | PLANT CAPACITY - TONS PER YEAR | | | |
|---|---|---|---|---|
| | 10,000 | 25,000 | 50,000 | 100,000 |
| Total Investment Capital | $630,000 | $720,000 | $740,000 | $1,130,000 |
| Investment/Ton/ Operating Day* | 5,250 | 2,400 | 1,230 | 940 |
| Investment/Daily Ton** | 15,750 | 7,200 | 3,700 | 2,830 |
| Direct Operating Costs/ Ton | 11.81 | 6.25 | 4.33 | 2.94 |
| Amortization Charge/Ton | 7.03 | 3.21 | 1.65 | 1.26 |
| Total Treatment Cost/Ton | 18.84 | 9.46 | 5.98 | 4.20 |
| Minimum Net Receipts from Sales of Products/Ton | 3.20 | 3.20 | 3.20 | 3.20 |
| Indicated Net Treatment Cost/Ton | 15.64 | 6.26 | 2.78 | 1.00 |
| No. of Employees (except Supervision) | 7 | 9 | 14 | 19 |

*An operating day here is a 24-hour day to operate 350 days/year.

**Based on 250 day-per-year operation at 40, 100, 200, and 400 tons/day in order.

plant design would indicate. In fact, installed power in these plants will be small compared with plants in which the total feed is pulverized in spite of the greater amount of equipment. The difference will be due to the almost total absence of crushers with heavy power requirements made possible by the elimination of mixed paper, wood and heavy metals.

It is interesting to realize that amortization over periods and at rates other than 20 years and 9-1/4 % have little effect on the operating costs of the larger plants. For example amortization over 10 years at 9-1/4 % would only increase total and net costs by about \$0.50 per ton for a 100,000 ton per year plant and a reduction of interest rate from 9-1/4 % to 8 % will only reduce the amortization charges by about 10 % for either the 10 or 20 year period. The 20-year and 9-1/4 % basis was chosen because it is currently employed by the City of Kingston.

At this point it is useful to recall the earlier observation that a reclamation plant is comparable to an ore beneficiation plant. Both facilities involve materials handling equipment of the same type and the costs of the composter might be equated with those for the fine grinding equipment. Moreover the effect of the different densities of garbage and ore on the unit cost is compensated by the massive volumes of water handled and the sophisticated separators, control systems, and dewatering devices normally included in beneficiation plant separation circuits. Thus it would appear to be reasonable to compare the capital investments of a beneficiation plant with those of a reclamation plant. For large installations where equipment capacities are used fully the capital costs of beneficiation plants in North America are not likely to exceed \$2000 per ton of daily capacity and, for plants using simple processes, costs of less than \$1000 per daily ton are reasonable. The estimates for the larger reclamation plants indicated in Table 8.2 are clearly approaching this range. Thus while this comparison does not constitute confirmation of the accuracy of the reclamation plant estimates it does lend credibility to them.

The capital costs per ton per day of feed, compared with the

TABLE 8.3: COSTS AND MANPOWER DISTRIBUTION IN A 50,000 TON PER YEAR PLANT WITH SEGREGATION

| ITEM | ANNUAL TOTAL | COST PER TON |
|---|---|---|
| Cost Distribution | | |
| Direct Labour | $105,000. | $2.10 |
| Overhead, Supervision & Sales | 76,200. | 1.52 |
| Power | 15,300. | 0.31 |
| Supplies and Maintenance | 20,000. | 0.41 |
| Amortization | 82,500. | 1.65 |
| TOTAL COSTS | $299,000. | $5.98 |
| Estimated Net Return from Sales | $160,000. | $3.20 |
| Estimated Net Plant Operating Cost | $139,000. | $2.78 |
| Labour Distribution | | |
| Sorting Belt | 6 | |
| Food Waste Feed Belt | 2 | |
| Processing | 2 | |
| Load-out & Haulage | 2 | |
| Maintenance | 2 | |
| TOTAL LABOUR FORCE | 14 | |

capital costs for composting plants presented earlier, (see Table 6.2) are clearly lower by a significant margin. The difference is attributable to the inclusion of disposal site costs in the composting unit costs and, as already noted, the cost of the composting operation is reduced by the reclamation process. Furthermore the material rejected from a reclamation operation of the type described can be used as 'clean' fill and its disposal is treated as a direct cost, not as a capital charge. In the reclamation section of the plant manual labour has been employed in preference to equipment for a similar purpose. This choice provides a greater flexibility in operation during the initial period in which markets are being developed. Thus capital costs are assuredly lower in this analysis than they might be in the future for this type of unit but in terms of evaluating the economic feasibility this is compensated by the higher operating costs resulting from the labour charges.

The revenue obtained from the sale of reclaimed materials and compost cannot be objectively verified as they will vary from city to city and with time. It is emphasized, however, that a very conservative estimate has been made of the potential markets and product values.

The costs for a small plant are heavily influenced by the high cost of a basic composting unit, the major equipment item, and by the comparatively large number of men who have been assumed to be necessary to operate the plant. If segregation is practised it may be advantageous to truck food wastes from a small community to a larger one for composting and disposal and to reduce thereby the capital requirements for a small community while also generating a larger flow through a plant. The economic advantages obtained by increasing the scale of the operation are clearly established by the data reported in Table 8.2.

## UNSEGREGATED COLLECTION SYSTEM

It is possible that a community will not choose to adopt a waste collection system that involves segregation, but this does not prohibit the operation of a reclamation process or make the manual

operations unduly objectionable. Inevitably, parts of the process will be less pleasant; some materials will not be recovered but at least a partial recovery of others can still be achieved. There is little or no problem in eliminating potential health hazards and providing good working conditions.

Non-segregated collection imposes limitations, initially at least, on the amount of material which can be assumed to be reclaimed. For example the recovery of newspaper is not impossible if it is mixed with garbage; hand sorting is still feasible but a mechanical separation or the Fibreclaim process (see Chapter 7) may eventually prove to be more effective. However, the amount reclaimed by any method will be reduced to a degree which will be dependent upon the form and extent of the mixing process initiated at the source of the waste and augmented by the collection operation. A possible exception is cardboard, since a major portion of the cardboard content of municipal wastes comes from business establishments, and it tends to be collected separately from food wastes. Its recovery should be a relatively simple matter. As indicated in Table 8.1 the recovery of cardboard without segregated collection has been assumed to be three-quarters of that obtained with segregation, recovery of glass is assumed to be half of that with food segregation and newspaper recovery is neglected altogether.

The load on the composter unit will be increased with the lower recovery of materials and it is possible that the composters provided for the largest plant will be inadequate for this tonnage. The overload which might be incurred is marginal and, in view of the uncertainties in estimating the degree of reclamation, the somewhat optimistic assumption of adequate capacity will be presumed.

As indicated in Figure 8.3 the process for this case involves a single treatment stream but most of the equipment described for the previous process with segregation will be required. As can be seen from the flowsheet the material from the feed unit is carried on a single belt which also serves as a sorting belt. This conveys the remainder of the waste to the coarse grizzly for removal of oversize. This portion of the plant would be well ventilated and could be

designed with 'air curtains' and possibly air conditioned if this was thought to be necessary. In contrast to the previous process a fine refuse separation would not be made and the crusher is required to handle all the unreclaimed material. Its purpose is to flatten cans and break bottles. The classifier then provides for the separation of material that is significantly heavier than water (e.g. metals and glass) from the remainder of the waste. The classifier products are dewatered and fed to separate bins or to the composting unit, as in the earlier process.

THE SORTING SYSTEM

This section of the plant is similar to that used in the system with segregation though only one conveyor is used. In practice less material will be removed from the belt than before but more labour will be devoted to opening boxes and bags to ensure that the bags of contaminated material are not included in the coarse refuse from the coarse grizzly unit. The necessity for a well designed ventilation system should be obvious and provision has been made for the cost of these facilities.

MECHANICAL SEPARATION SYSTEM

The purpose of this crusher is to facilitate the separation of the glass and metal and, as in the previous process, a roll crusher would seem to be most appropriate. In this case the crusher will receive a greater fraction of the total plant feed and will be required to handle larger objects than the equivalent unit previously considered.

The load on this unit might be reduced by introducing a second size separation in the coarse grizzly so that both the oversize and the bulk of the fines, including most food wastes, are kept out of the rolls crushers. The oversize would then be delivered to the refuse bin as indicated, the fines would be transferred directly to the cage mill and only the intermediate material would be crushed and subjected to the glass and metal separation process. This arrangement has not been shown in this study in order to simplify the understanding of the process. This refinement is one that has only a minor effect on the

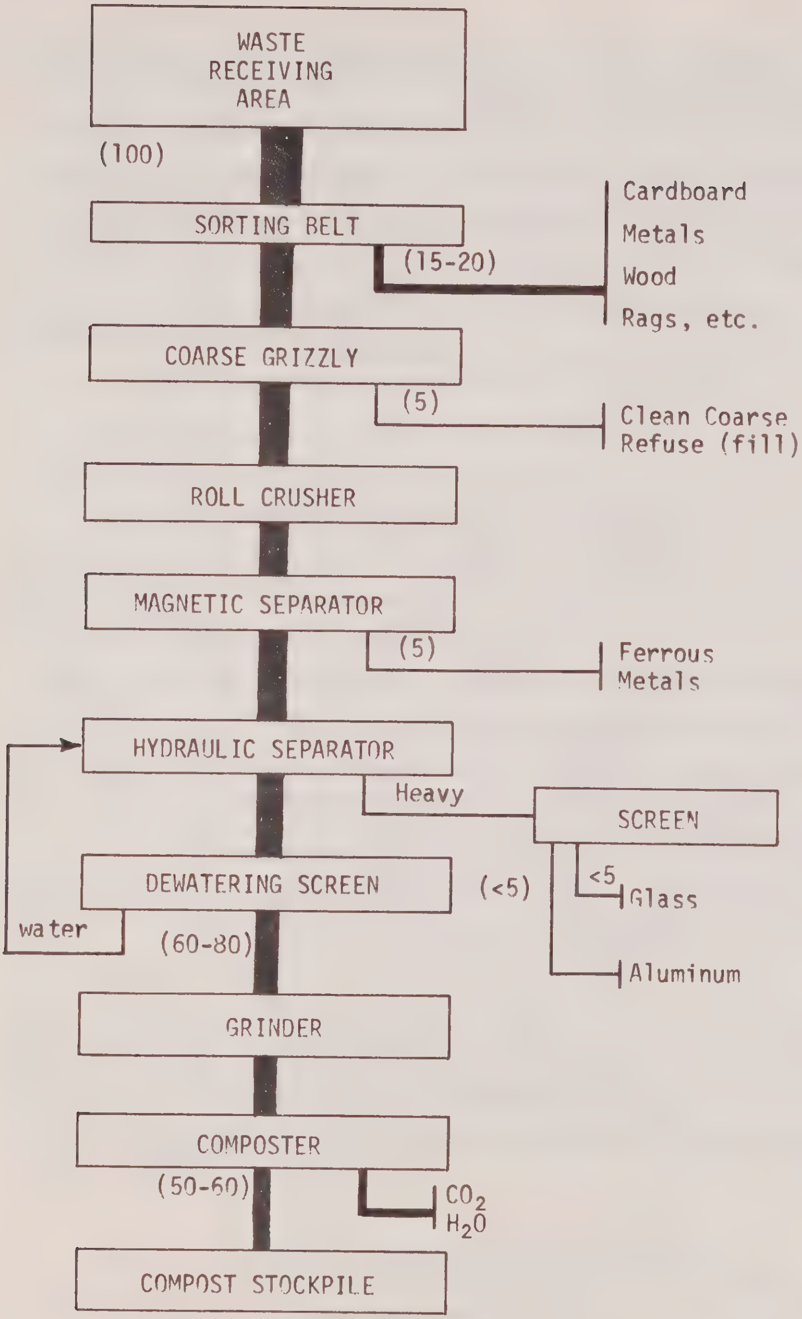



FIGURE 8.3: RECLAMATION PROCESS FOR UNSEGREGATED WASTE (Bracketed numbers indicate percent of total feed in stream).

capital and operating costs and could be included after experience has been obtained with the simpler system.

Magnetic separator: This unit will be similar to that previously described but the recovery of ferrous metal and cans will be less effective due to the mass of paper present. Fortunately a further extraction of magnetic materials can be accomplished at a later stage in the process if this is found to be necessary.

Classifier: The purpose of this unit is to provide a separation between the light and heavy constituents of the waste stream. A conventional rake or spiral classifier could be used. The heavier particles consisting almost exclusively of glass and metal sink while the light material which is primarily paper together with food wastes and plastics float. The heavy material is extracted from the pool by a rake or screw mechanism. The water is extracted from the overflow stream on a screen and recycled to the classifier.

The subsequent milling of the 'light' stream in a cage mill will be facilitated by the partial immersion of the paper in the water system. However the residence time in the classifier should not be so great as to saturate the paper completely and only a dewatering screen system should be required prior to composting this stream.

Cage Mill: This device will have a higher power requirement than that previously described, probably in proportion to the increase in paper content of the feed material. The power consumption and cost of this step will remain, however, far below that normally required for pulverization.

Screen: The heavy material recovered from the classifier will be passed over a screen to separate glass from metal, mostly aluminum, as

in the previous process. In this case, the material will be wet and it may be necessary to spray water on the screen to facilitate the separation. However that will not be novel and the water draining from the products can be used as a make-up water supply for the classifier.

COMPOSTER AND COMPOST PILE

These elements will be identical with those in the other system.

DISCUSSION

The process will function in a manner similar to that previously described but differences in costs are to be expected due to the increase in mechanical equipment and the lower recovery of values. This is reflected in the capital and operating cost estimates for this process which are presented in Table 8.4. It may seem that the capital investment for the process without segregation is very similar to that for the segregated system; the small differences are due to provision of slightly larger equipment for the unsegregated plant.

Operating costs for the plant without segregation are slightly lower than for the segregated plant, primarily because a smaller labour force is employed. However even that difference is not great and it would be an unrealistic basis for conclusions. Of more significance is the fact that the recovery of materials for the unsegregated feed system are much lower. This can be seen by comparison of the data in Table 8.5 which gives costs and manpower distribution for a 50,000 tons per year unsegregated feed process with data for the segregated feed system reported in Table 8.3.

## GENERAL DISCUSSION AND CONCLUSIONS

The reclamation processes which have been described in this chapter involve no novel features and rely on combinations of units whose performance cannot be seriously questioned. All the equipment chosen to illustrate the feasibility of the process is standard and is available from a number of manufacturers. The result is that no

TABLE 8.4: COST ESTIMATES FOR A RECLAMATION PROCESS WITHOUT ANY SEGREGATION

| | COST ESTIMATES FOR DIFFERENT PLANT CAPACITIES - TONS/YEAR | | | |
|---|---|---|---|---|
| | 10,000 | 25,000 | 50,000 | 100,000 |
| Total Invested Capital | $650,000 | $760,000 | $780,000 | $1,170,000 |
| Investment/Ton/ Operating Day | 5,420 | 2,530 | 1,300 | 980 |
| Investment/Daily Ton | 16,250 | 7,600 | 3,700 | 2,930 |
| Direct Operating Costs/Ton | 10.78 | 5.54 | 4.00 | 2.74 |
| Amortization Charge/Ton | 6.90 | 3.25 | 1.67 | 1.27 |
| Total Treatment Cost/Ton | 18.03 | 9.13 | 5.74 | 4.05 |
| Minimum Net Receipts From Sales of Products/ Ton | 1.70 | 1.70 | 1.70 | 1.70 |
| Indicated Net Treatment Cost/Ton | 16.33 | 7.43 | 4.04 | 2.35 |
| No. of Employees (except Supervision) | 6 | 8 | 12 | 16 |

TABLE 8.5: COSTS AND MANPOWER DISTRIBUTIONS FOR A 50,000 TON/YEAR PLANT WITHOUT SEGREGATION

| ITEM | TOTAL | PER TON |
|---|---|---|
| Direct Labour | $90,000. | $1.80 |
| Overhead, Supervision & Sales | 69,600. | 1.39 |
| Power | 13,300. | 0.27 |
| Supplies | 5,000. | 0.10 |
| Repairs | 22,000. | 0.44 |
| Amortization | 87,000. | 1.74 |
| TOTAL | $286,900. | 5.74 |
| Estimated net receipts from sale of recovered materials | 85,000. | 1.70 |
| Net Operating Cost | 198,500. | 3.97 |
| Labour Distribution- Sorting Belt | 6 | |
| Digester, Screwing & Handling | 2 | |
| Load-out | 2 | |
| Repairs, Maintenance & Security | 2 | |

problem requiring new technology should arise in the operation of these processes, although the development of refining or reprocessing techniques for recovered materials might be indicated as new markets for these materials are explored.

A summary of the cost data for both processes is given in Table 8.6. The capital and operating costs for reclamation from a segregated waste feed may be seen to be marginally lower at all levels of operation. This might be understood to indicate that segregation of the putrescible fraction is unwarranted. It should be realized, however, that the desire to provide a very conservative estimate of the reclamation revenues has led to an underestimate of the potential benefits of segregation. Furthermore the net revenue has been deliberately minimized by the assumption that there will be an additional collection cost of $1 per ton which will be charged to the reclamation process.

It is interesting to note that the estimated reclamation revenues are of the same order as those reported for the operation conducted by the Sanitary Refuse Collectors of Montreal[1]. In this process a net profit of $0.57 per ton was obtained for the salvage operation. The equivalent estimated figure is approximately $0.50 per ton as may be deduced from Table 8.5 by separating the direct costs of the salvage operation. Such favourable comparison should only be taken as an indication that the revenues estimated are achievable and are probably conservative in nature.

Reclamation systems of the form described in this study have the important characteristic of being adaptable to changes in feed composition and to significant increases in capacity, in contrast with many of the processes previously described. This statement applies not only to the composter unit but also to the reclamation equipment since the equipment size is defined by the physical size of the individual items of the waste and not by the tonnage handled. For example the width of the sorting belt is the same for all capacities and the capacity of this unit can be readily increased by increasing the belt speed and the sorting labor. A further increase could be achieved

1. Johnson, J. "Refuse Reduction Plant Montreal-Quebec, Engineering Journal June 1969, p. 15 - 21.

TABLE 8.6: TOTAL COSTS OF RECLAMATION SYSTEMS

| ITEM | COST FOR PLANT OF CAPACITY AND PROCESS SHOWN | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10,000 | | 25,000 | | 50,000 | | 100,000 | |
| | Segregated | Unsegregated | Segregated | Unsegregated | Segregated | Unsegregated | Segregated | Unsegregated |
| Total Capital Investment ** | 630,000 | 650,000 | 720,000 | 760,000 | 740,000 | 780,000 | 1,130,000 | 1,170,000 |
| Collection Surcharge | 1.00 | ---- | 1.00 | ---- | 1.00 | ---- | 1.00 | ----- |
| Total Treatment Charge | 18.84 | 18.03 | 9.46 | 9.13 | 5.98 | 5.74 | 4.20 | 4.05 |
| Coarse & Fine Refuse | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Cardboard, Newsprint, Glass, Metals | (3.20)* | (1.70) | (3.20) | (1.70) | (3.20) | (1.70) | (3.20) | (1.70) |
| Non-saleable Metals | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Saleable Metals | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Wood | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Compost | 0.36 | 0.45 | 0.36 | 0.45 | 0.36 | 0.45 | 0.36 | 0.45 |
| Total Disposal Charges (excluding credits for sale of Cardboard, Newsprint, Glass & Metals) | 20.50 | 18.78 | 11.12 | 9.83 | 7.64 | 6.49 | 5.86 | 4.80 |
| Net Disposal Cost | 17.30 | 17.08 | 7.92 | 8.18 | 4.44 | 4.79 | 2.66 | 3.10 |

*(Brackets denote credit)
**Investments in dollars, all other costs are $/Ton of plant feed

simply by extending the length of the belt or by providing a second unit.

Reliance has been placed on manual labor for the first part of the reclamation process and the estimates for the work force required are similar to those reported in the literature for this type of operation. Perhaps the best comparison which can be made in support of these estimates is to note that the Houston, Texas, reclamation plant which has a capacity of 360 tons per day employs 29 operators whereas the simpler and more mechanized reclamation process described in this study is estimated to require 19 operators, excluding supervisors, for a capacity of 400 tons per day. The additional 10 men required for the Houston operation would probably be needed for drying, bagging and warehousing operations, which are not required in the processes described in this study, and for operations which have been mechanized. The most critical issue is the number of operators required for the manual sorting operation. As a test of the effect of errors in estimating this, the overall costs generated by doubling the sorting labor work force have been calculated and are reported in Table 8.7. This data represents a gross overestimate of the reclamation costs but nevertheless indicates that reclamation operations are still economically feasible.

In this preliminary analysis of the feasibility of reclamation processes it has been presumed that the units will be operated on a basis of a 40 hour, 5 day week. The economy of operating a three or four day week with the operating labour employed for other purposes in the community has not been investigated. It is also possible that with a routine manual operation of the kind initially envisaged far greater efficiencies and better operating labour can be obtained by operation for a 35 hour, 4 day week. These variations remain to be explored, but are so specific to the individual community's requirements as to be beyond the scope of this study.

The additional benefits obtained by the incorporation of a sewage disposal operation in combination with the composting operation have not been examined. There is reason to believe that this could result in a reduction of sewage plant costs, and a more effective

TABLE 8.7: EFFECTS OF ADDITIONAL LABOUR REQUIREMENTS ON RECLAMATION PLANT OPERATING COSTS

| ITEM | PLANT CAPACITY | | | |
|---|---|---|---|---|
| | 10,000 | 25,000 | 50,000 | 100,000 |
| System with Food Waste Segregation | | | | |
| Direct Operating Cost/ Ton per Table 8.2 | $11.81 | $ 6.25 | $ 4.33 | $ 2.94 |
| Additional costs with doubled sorting belt labour | 2.16 | 1.29 | 1.29 | 0.86 |
| New Direct Operating Cost/Ton | 13.97 | 7.55 | 5.63 | 3.80 |
| New Net Cost/Ton | 17.80 | 7.55 | 4.07 | 1.86 |
| System without Segregation | | | | |
| Direct Operating Cost/ Ton per Table 8.4 | 10.78 | 5.54 | 4.00 | 2.74 |
| Additional Cost with Doubled Sorting Belt Labour | 2.16 | 1.28 | 1.29 | 0.86 |
| New Direct Operating Cost/Ton | 12.94 | 6.84 | 5.29 | 3.60 |
| New Net Cost/Ton | 18.49 | 8.71 | 5.33 | 3.21 |

sewage treatment process. In terms of solid waste treatment, the present problem of the disposal of sewage plant digestor solids would be solved and in turn the value of the compost product would be enhanced. These benefits serve to make the reclamation processes described in this study even more attractive.

Reclamation systems might also provide the answer to the most vexing problem of public acceptance. All products from the process are sterile, provide few pollution hazards and do not require the operation of a traditional disposal site. The first reclamation unit in Canada should also satisfy the public that a reclamation unit can be operated with no more public nuisance than that created by a light industry. At this point, reclamation units of 100,000 tons per year capacity might be considered in preference to transfer stations within large cities.

Finally it should be emphasized that within the next decade the reclamation and recycling of waste materials will become an ecological necessity. A public demand for progress in this area is beginning, and will grow.

# CHAPTER 9

## VALUE AND UTILITY OF RECLAIMED MATERIALS

Materials are currently valued on the basis of their sale price. For example, during the recent world shortage of nickel, the price of scrap nickel rose above the normal price for refined metal. Thus with an increasing world population and the depletion of many of the non-renewable resources for energy and minerals it is certain that prices of reclaimed material will rise in accord with the demand.

The current price of a material is one measure of its value but it fails to incorporate the cost of expending the natural resources or the very real ultimate cost of the effect of the unwanted bi-products liberated during the extraction and processing of the material. Society is not yet prepared to include these 'latent' costs in establishing the true values of materials but it is evident that this realistic appraisal cannot be indefinitely deferred.

At the present time the case for reclaiming a material must be based on the economic return which is currently available. Even this is difficult to assess since many reclaimable materials have not been produced in sufficient quantity to establish a true market value. Furthermore the lack of industrial processing experience with reclaimed material has delayed the establishment of standards of acceptance for these materials. It is also conceivable that the development of reclamation units will stimulate the creation of new products and processes which in turn could change the price structure for some materials.

The value and market for a reclaimed material cannot be stated therefore with the certainty that is normally demanded for the evaluation of a new process.

### PAPER

In its many forms paper is the largest single component of municipal waste. Newspapers and cardboard are the most readily

recoverable items and a market for these could be developed in Ontario. There is also a demand for recovered clean high quality papers but unless these are generated in quantity by a local business and collected separately it is difficult to conceive how this product can be reclaimed economically from municipal waste. Recovered cardboard and newspaper will therefore constitute the major paper products from a reclamation process.

Table 9.1 presents a review of the New York prices for reclaimed paper. Similar data has been reported for the cities of Boston, Chicago and Los Angeles. It will be noted that the process fluctuates, presumably with the price of virgin pulp, but the recent trend shows a slackening in demand for recovered newspaper with a rise in the value of cardboard. These figures are said to provide an indication of the Canadian market prices but it should be realized that the reclaimed paper market has been relatively insignificant in Canada and firm prices have not been established.

The authors were surprised to find that paper companies in Canada are actively investigating the possibility of using a far greater fraction of reclaimed paper. It was said that the proportion of virgin pulp used by the industry must be decreased in future years as the demand for paper rises. The major problem which confronts the industry is not the method of reprocessing but the development of reliable sources of reclaimed paper.

The creation of reliable long-term sources of reclaimed material appears to be the crux in the development of the market for most reclamation products. It is unrealistic to expect voluntary organizations or small businesses to provide a satisfactory source and thus the development of the market awaits the evolution of an economically sound reclamation system.

It is concluded therefore that in this 'chicken and egg' situation that a prototype reclamation system must be shown to provide a guaranteed output of clean reclaimed paper before the market can be properly assessed. Refinements of the reclamation process such as the inclusion of repulping and cleaning operations might be deferred until this preliminary appraisal has been made, or might be a part of it.

TABLE 9.1: SELECTED WASTEPAPER PRICES IN THE NEW YORK AREA
(From Paper Institute Journals-Dates Indicated)

| DATE | NO. 1 MIXED PAPER | NO. 1 NEWSPAPER | OLD CORRUGATED CONTAINERS | SUPER PRESORTED KRAFT CONTAINERS | TAB CARDS | MIXED BUNDLES & MAGAZINES |
|---|---|---|---|---|---|---|
| Feb. 8/68 | $ 5.00/ 9.00 | $ 22.00/ 29.00 | $ 12.00/ 19.00 | $ 20.00/ 22.50 | $ 57.50/ 62.50 | $ 8.00/ 10.00 |
| June 17/68 | 10.00/ 11.00 | 18.00/ 20.00 | 17.00/ 19.00 | 20.00/ 21.00 | 57.50/ 61.50 | 8.00/ 9.00 |
| Dec. 16/68 | 8.00/ 10.00 | 20.00/ 22.00 | 17.00/ 19.00 | 22.00/ 23.00 | 57.59/ 61.50 | 8.00/ 9.00 |
| Jan. 13/69 | 8.00/ 10.00 | 20.00/ 22.00 | 17.00/ 19.00 | 22.00/ 23.00 | 57.50/ 61.50 | 8.00/ 9.00 |
| July 28/69 | 5.00/ 8.00 | 15.00/ 17.00 | 17.00/ 22.00 | 22.00/ 23.00 | 65.00/ 77.50 | 8.00/ 9.00 |
| Dec. 1/69 | 5.00/ 6.00 | 13.00/ 14.00 | 17.00/ 25.00 | 22.00/ 23.00 | 65.00/ 75.00 | 8.00/ 9.00 |
| Jan. 26/70 | 5.00/ 6.00 | 11.00/ 14.00 | 17.00/ 25.00 | 22.00/ 23.00 | 65.00/ 80.00 | 7.00/ 9.00 |

GLASS

In many ways the glass industry resembles the paper industry. Both industries handle large quantities of raw materials to produce a variety of low cost items which are widely distributed and both have the desire to develop a recycle system for reclaimed materials.

The motivations for this desire are different since the raw materials for glass manufacture are in abundant supply being probably adequate for another three billion years at the present rate of consumption. Glass, in contrast with paper, does not degrade and presents a very obvious disposal problem, a fact which recently has been a public issue. The activities of the industry to investigate methods of recycling and reuse of glass have therefore been as much a matter of self interest as of concern for the environment. The industry, by its support of the work of the Glass Container Manufacturers Institute and the Glass Container Council of Canada, has probably made more significant progress in this direction than any other comparable industry. As a result, methods for reuse and recycling have been developed and the industry only awaits the development of a large scale reclamation operation to implement them fully.

Attempts to encourage the return of bottles have met with limited success. In the United States, for example, one cent per pound is being offered for returned bottles and although this has substantially increased the percentage returned it is estimated that no more than 5 percent of the bottle production can be recovered in this way. The return of bottles to the product manufacturer has been encouraged for some products by charging a deposit. This might be the only way to avoid extensive littering of the roads and recreational areas. It is certain, however, that whatever success is achieved by these means a substantial proportion of the glass produced will continue to be found in the municipal waste. A process for the reclamation of glass from municipal waste would be welcomed, therefore, by the glass industry.

At the present time glass manufacturers would be prepared to offer $15 per ton for coloured glass and $20 per ton for clear

glass in carload lots. The manufacturers prefer a separation of the glass into clear and coloured streams since clear glass can be coloured by the addition of materials to the melt but no practical system exists for converting coloured glass to clear material. In any case it is vital that the composition of the glass is constant and further, for remelting purposes, the glass must be free from metals and other foreign material which could be incorporated in the glass during the remelt process.

Glass is a stable mineral material that can be used in other applications. For example the glass industry has explored the combination of glass and asphalt in which the conchoidal fracture of glass may make it an attractive component for road surfacing. Pavements containing glass may reduce auto skidding somewhat. Also glass is harder than the crushed limestone often used in paving mixes and so may wear better. For such markets, however, glass would be competing with crushed stone and even if glass were demonstrably better, its value would still be in the same range as crushed stone, probably not greater than about $5 per ton.

Neither is there anything to prevent the use of glass in new products. For example glass could be melted or cemented into building materials to substitute for slate in flooring or roofs and for bricks. The production of lightweight building materials from waste glass is in fact being investigated at Stanford University. In fact these outlets are particularly attractive for the more remote centres where shipment costs may not allow direct recycle. However use in building products will only be attractive under two conditions: the area must have no competitive material available or a special appearance must be developed to provide a special product. In competition with other masonry materials a glass product must sell for about $25 per ton and at this price the net return after manufacture, advertising, and distribution to the reclamation plant will probably be no more than about $8 per ton, about the same as for road surfacing for which no major investment is required. The price for a specialty product will be higher but production costs will also be higher and advertising and distribution costs are incurred.

It can be concluded that a market for recovered glass exists

and prices between $5 to $20 per ton, dependent upon the final use, should be obtained for this reclamation product.

FERROUS METALS

It is impossible to make a realistic appraisal of the value of ferrous metals reclaimed from municipal wastes since reliable analyses of the metal content are not available and the existing market for scrap in Canada is in the state of change.

One major question concerning ferrous scrap is the future of the "tin" can. These are no longer made of tin, but of light-gauge steel with small amounts of solder, varnish and other materials to extend their corrosion resistance and shelf-life. Moreover many snap-top cans have steel bodies with aluminum ends. Clearly magnetic separation provides a reliable technique for extracting cans from garbage but a problem exists once the can is removed. It is difficult to remelt light-gauge metal and no other market of any volume exists in Eastern Canada.

The problem with light-gauge metals results from the relative stabilities of carbon dioxide and iron oxides (and therefore by the stability of iron in oxygen) at temperatures below the melting point of steel. Put simply, cans will oxidize to iron oxide before they melt. In heavy-gauge metals the surface of the metal oxidizes in the same way but the fraction of the total iron lost to oxide is small; in cans, a major portion is lost. Moreover the loss includes not only the metal itself but also the heat required to raise it to oxidation condition. Losses are diminished when the cans are compacted into bales but some loss is unavoidable and baling is costly.

The oxidation problem can be avoided, of course, if oxygen and oxides are eliminated during melting. However this is difficult and expensive. At the same time, the recovery of iron in cans by chemical or electrolytic methods to produce iron powder can be applied to other equally suitable forms of iron scrap so no great potential can be assigned to that approach.

There are unconfirmed reports that the steel industry has developed techniques for reuse of can scrap but no information or details are available at this point. Accordingly, the authors see no

realistic recycle route for cans; instead it is suggested they should be a clean fill in which role there is no basis for doubt, no pollution hazard and some prospect for a small revenue.

In brief, no basis can be presented on which a noteworthy return for the recovery of scrap iron can be claimed from municipal wastes. Undoubtedly some return will be generated but neither a large nor a consistent value can be predicted.

NON-FERROUS METALS

The market potential for non-ferrous metals is much greater than that for ferrous metals and markets for these materials already exist. Precise estimates of the market price cannot be given, however, since much will depend upon the purity of metals and the tonnage recovered.

A profitable market should be available for recovered aluminum arising mainly from the aluminum cans now used to contain drinks of all kinds. The fraction of aluminum recovered from municipal refuse will, however, depend upon the form of the material. The aluminum in the caps of some steel cans will probably be lost with the steel can whereas aluminum caps and ends of cardboard cans will be combined with the crude compost product. The price which can be obtained depends upon the tonnage which can be guaranteed and at this stage this is not predictable. Unquestionably the metal value of $10 per ton which might be assumed to be the average value of the reclaimed non-ferrous metal product is an ultra conservative figure if the scrap contains a significant proportion of aluminum scrap.

Reclaimed copper and brass could form an important source of revenue but the quantity and form of this material is not known. As before, investigation of the market must await a more detailed analysis of the composition of a municipal waste and the reclamation process.

Large non-ferrous items can be manually separated and stock-piled to form an acceptable quantity. This material would then be sold at the prevailing local scrap metal price. It is suspected, however, that much of the non-ferrous metal is present as light-gauge items

which could be chopped, screened and separated using density separation techniques. If this separation process is used, the aluminum chips could find a lucrative market in explosives manufacture. Approximately 400,000 pounds per month of this form of aluminum is currently being used in Eastern Canada at a sale price of between 20 to 32 cents per pound. This profitable market has already been recognized by a Kansas City firm who supply 50,000 pounds per month from reclaimed material to a South American mine for a price of 21.5 cents per pound f.o.b. Kansas City.

Other metals including tin, lead, chrome, nickel, silver and even gold have been reported to be present in municipal wastes. The quantities involved are small and the difficulty of isolating these materials is expected to be so great that markets for these materials have not been investigated.

## PLASTICS AND RUBBER

This category of products contains a preponderance of rubber materials followed in order of amount by polyethylene, polyvinyl-chloride (P.V.C.) and polystyrene.

With the exception of large items, such as tires, it is not possible to separate the individual rubber and plastic items. In a reclamation process most of the plastics and rubber items will leave the system mixed with other products and, if the compost is partially refined, as a partially chopped mixture of materials. Recovery and reuse of much of this material is neither practical nor economically feasible at this time and no markets exist. Fortunately all these materials are essentially inert and can be used safely in a landfill project.

The manufacture of weeping tile using waste plastic as a binder has been reported and it is possible that other similar low grade materials could be produced. Undoubtedly the production of mixed plastic product in quantity from a reclamation unit will stimulate the creation of new products. The possible use of waste plastics and rubber in a future pyrolysis unit should not be overlooked since for this purpose they could generate a revenue

equivalent to the price obtained for other fossil fuels.

## FOOD WASTES

Food wastes have not been mentioned as a possible reclamation product so far in this study. They tend to be regarded solely as a putrescible material which can cause severe vector problems in the operation of a dump or landfill system. The opportunity of using this fraction of domestic waste to provide a source of food for animals or even people, has been given little attention therefore in the literature.

Those communities which have separately collected kitchen wastes for animal feed are reported to find this operation to be economically attractive. Many have now discontinued this practice, however, after the imposition of local or national health regulations or perhaps because kitchen wastes are now becoming mixed with objectionable materials.

Food wastes could form a valuable reclamation product and more attention might be given to sterilization and separation techniques to provide a product which, at the worst, is acceptable as animal feed. No market for this material exists in Ontario although its creation would not appear to be a difficult task if a satisfactory product could be developed.

In the reclamation process described in this study the composting route has been chosen as the method of treatment for food wastes. This choice is based on the potential usefulness of the compost product, on the desire for a sanitary product whose disposal presents no problems, on the cost of this operation and the ability of the process to treat a wide range of materials.

## COMPOST

The production methods and general characteristics of the compost product have been described in Chapter 6. No current market for this product exists in Canada and it is apparent that considerable effort would need to be expended to generate its widespread acceptance by the agricultural community. Thus in costing the reclamation processes the compost product has been charged with a disposal fee.

The desirable characteristics of compost, particularly its ability to serve as a soil conditioner, have been recognized in Europe and by some communities in the United States. It is believed, therefore, that the pilot scale production of compost in Canada would enable potential users to assess its benefits more accurately, which in turn could lead to the development of a substantial market for this material.

Compost, as produced, contains 50 percent moisture, is dust free and has many characteristics of peat moss. It can be stockpiled without protection from the weather. The market may eventually demand a bagged or pelletized product but these operations greatly add to the costs of both production and distribution. The utility of the bulk material will therefore be emphasized.

Compost additions to the soil ranging in amount from 10 to 200 tons per acre have been found to have a beneficial effect. Thus the yet unexplored possibility of creating top soil reserves is suggested as a long term use for compost. For example with an application of 100 tons per acre, 150 acres of poor land could be upgraded by the compost produced from a plant serving 50,000 persons. Properly managed and with the annual addition of poor soil these 150 acres could serve as a continuous source of good quality top soil for the community. It is possible that a similar result could be obtained by mixing low grade soil with compost at the composter site. Mineral tailings might profitably be substituted for low grade soil in some areas for this purpose.

Compost has also been used as a bedding material for seedlings, mushroom production and tree saplings. The benefits to be obtained are well documented. It is possible, therefore, that a market for these specialized uses could be developed.

It has also been demonstrated that compost can be used to stabilize land and prevent soil erosion. Thus compost could be extensively used in stabilizing embankments and in reforestation projects. The method which has been developed of spraying compost, fertilizer and seed mixtures in a slurry form could greatly facilitate these operations. It is said, for example, that grass can be made to

grow on telephone poles using this technique. The market which might be developed for these purposes is restricted, however, by the cost of hauling the compost to the site of the operation.

There is evidence that the presence of compost in the soil reduces the leaching of chemical fertilizers. Thus compost could assist in reducing the pollution of water bodies with artificial fertilizers and could increase the effectiveness of the fertilizers. A more detailed evaluation of this effect followed by discussion with the agricultural community could lead to a heavy demand for compost and possibly to the acceptance of pelletized compost premixed with artificial fertilizers.

The technology and agricultural benefits of compost are relatively well understood.and it is confidently predicted that a market for this material could be developed in Canada.

OTHER MATERIALS

Municipal wastes also contain materials such as wood, brush and rags for which a value could be claimed. No attempt will be made to do so since the quantity and quality of these items is unknown.

Rags might be reclaimed on a sorting belt and could be sold as such if the form and quantity merited their extraction.

The larger and more valuable pieces of wood could be extracted from the waste and might be sold directly to the general public at the waste treatment site. It is anticipated that little more than the cost of its recovery could be charged for this material. This arrangement could at least save the cost of disposal and could afford some benefit to the community.

Brush composed of tree and shrub trimmings ranging from twigs to trunks can be buried without hazard but it is pointless to do so if a use can be found for this material. If a chipping unit is installed this material could be added to the composter and if wet sewage sludge is being treated simultaneously the operation of the unit might be considerably improved. Larger tree sections might be stockpiled until they have cured to the point at which they could be sold for firewood. Again little, if any, profit is to be expected from such an operation

but the disposal costs are marginally reduced and wastage is avoided.

DISCUSSION

The attempt to investigate markets for materials which might be reclaimed from municipal refuse has been seriously hampered by uncertainty as to the amounts of the various materials present and the amounts that could be recovered. For example outlets exist for metals, both non-ferrous and ferrous, but the values assignable to these metals is dependent on their quantity and form.

Similarly it is known that major markets exist for reclaimed paper and glass though for these materials the potential of the market depends on continuity of the supply as well as on its quality and quantity.

Moreover, of all the new products considered, compost may have the highest potential for a future market in Canada if only because it will be produced in large quantities. However a realistic assessment of compost or of any constituent of the waste requires that at least pilot scale quantities of material be available for exploration.

# CHAPTER 10

## REGIONAL COLLECTION

In common with other industrial processes the cost of treatment or disposal of waste materials decreases as the tonnage handled rises. This result is reflected in the individual cost-capacity relationships given in the previous chapters . It will be noted that the unit cost is dramatically affected by a change of capacity in the range of 5,000 to 15,000 tons per year but for a number of the processes considered little would appear to be gained by increasing the capacity beyond 100,000 tons per year.

This simple analysis suggests that in areas of low population density a centralized treatment facility should be created whereas in the larger centres of population facilities of approximately 100,000 tons capacity might be installed in preference to transfer stations.

The development of an optimum system for waste management for Ontario is a matter of urgent concern but is not within the scope of this study. However a preliminary analysis of the practicality of providing centralized facilities for rural areas would seem to be appropriate since small communities cannot afford to operate a disposal system in strict accordance with the intent of the Waste Management Act. Indeed, this fact is recognized by the regulations issued by the Waste Management Branch.

This chapter provides, therefore, a brief review of the problems and possible situations which need to be considered by rural and small communities.

### THE PROBLEMS

The most obvious problem to be faced in the development of a rural collection system will be the reluctance of individuals and communities to co-operate in such a scheme. Open dumps, operated under the supervision of the public health officers, are far less expensive to operate than a centralized facility. Unless future regulations

prohibit the operation of such dumps, only a few enlightened communities could be expected to be interested in a proposal for regional treatment.

The successful operation of a regional facility will be dependent on the development of an economic collection system and on the provision of low cost transfer stations. The area served by the regional system will be determined by the cost of this collection system, the treatment process and by the available road network. The location of the nearest town in which the centralized treatment plant might be situated will also have an important effect on the regional plan. It is clear that these factors demand detailed consideration for each potential region and no general solution can be evolved in this study.

The composition and quantity of the waste generated by a rural community is unknown. Some guidance might be obtained from the unit figures developed by the authors of the SERL report but Canadian data is needed before the possibilities of regional collection from rural communities can be properly assessed. For example it is possible that the contributions from commercial sources to municipal wastes will be lower in smaller communities than in larger centres because the volume of business may be smaller. However this might be compensated by the inclusion of agricultural wastes in smaller communities and, on balance, it seems reasonable to assume for the present that the waste production rates and composition in all communities will be comparable.

The potential benefits of incorporating the waste from rural communities with those from a neighbouring town need to be emphasized to encourage the development of realistic solutions to these problems. The following example analysis is presented with this in mind.

## EXAMPLE OF REGIONAL OPERATION

It will be assumed that the nature of the region and the treatment process is such that the following conditions are valid:

1. A central community will be prepared to operate a treatment facility with a capacity to handle 50,000 tons per year.

2. A potential supply of an additional 100,000 tons of waste per year exists in surrounding communities having individual waste flows of up to 20,000 tons per year but averaging less than 10,000 tons per year.
3. Landfill disposal systems are not acceptable for most of the communities involved or the communities are willing to avoid this approach.
4. If a central facility to treat 150,000 tons per year is established the savings in treatment costs will average about \$2 per ton or a total of \$300,000 per year for the area. This estimate is in accord with the savings attainable through the scale increase from 50,000 to 150,000 tons per year.

The problem then reduces to the determination of the maximum distance over which a collection system might operate, i.e. will the savings in treatment costs justify the haulage over the distance required to encompass the communities producing the additional 100,000 tons per year. An answer requires an estimate of the cost of haulage and of the cost of transfer stations. Of these the haulage cost is the simpler and will be dealt with first.

Because collection is envisaged from a number of small centres it is appropriate to plan on truck transport for the wastes though a rail system may be appropriate for some communities. In addition, it can be assumed that a sizeable fleet of trucks (tractor-trailer units) will be involved so that they will be specially designed and will operate 24 hours per day. This continuous operation is vital not only to lower costs but to avoid delays in the collection of wastes from transfer stations. After considering these features and other requirements of a trucking business, one trucking company executive estimated that an operating cost for a 20-ton truck of \$0.50 per mile is a reasonable basis for a preliminary calculation. This estimate is consistent with estimates that have been made for another major centre where costs estimated for haulage in the collection vehicle on expressways or freeways at an average speed of 40 m.p.h. was \$0.13 per ton per mile. This was approximately equivalent to \$0.65 per mile for

the application in question. The difference in the present estimate is attributable to the much larger load involved in the present proposal, the type of transport involved and different operating schedules.

Haulage of wastes by rail is entirely reasonable especially for large cities where large tonnages are involved and has been studied extensively in the U.S.A. However for small communities the method is not likely to find much application for at least three reasons: costs will be higher, scheduling of pick-ups will be difficult, and rail freight service is not available for most small communities.

One aspect, common to both the rail and road haulage systems, is the possibility of using trailers, parked at specific locations, which would be loaded by local collectors and hauled to rail cars for "piggyback" transfer or directly to the treatment plant at night. This approach is not particularly attractive for several reasons. A trailer unit is expensive, difficult to load and unload and either would tend to be of such size that road haulage would be unduly expensive or scheduled pick-ups would be too infrequent.

A more attractive solution would appear to be to employ steel containers of approximately 5 tons capacity which would be deposited at and collected from suitably designed transfer sites using a flatbed truck. Alternatively low compression baling equipment might be installed at convenient sites and the bales transported using a flatbed truck. In both cases the truck should be fitted with a mechanical loading device similar to that employed for handling palletized building materials so that the unloading and loading operations can be accomplished with the minimum of labour.

The installation of baling equipment might be a more attractive proposition for long distance haulage since the higher compaction densities achieved could significantly reduce the haulage charge. On the other hand this equipment requires the attention of an operator or necessitates an additional operation by the local collector.

For the purpose of this estimate it will be assumed that local collectors will use conventional packers and that material will not

expand significantly during transfer. Thereby the waste in the transfer vehicle may have a density of about 16 pounds per cubic foot. This assumption is probably optimistic but as the potential for devising a simple compacting device to exploit the regular shape of the containers is neglected the optimism is not unreasonable.

The cost of transfer stations of this kind will be determined by the cost of the containers, and the cost of the land and its preparation to provide a ramp surface for truck discharge into the containers. A total cost of $7,000 is estimated to be a generous allowance for this simple form of transfer station to handle one container. This includes $3,000 for the container, $3,000 for the ramp and $1,000 for purchase of the land and its preparation. Probably, the smallest transfer station of this kind would be one designed to handle the waste for a community of 1000 people and would involve facilities for three containers at a cost of approximately $20,000. For larger communities the number of containers required would be less in proportion and an average of 1.5 containers per 1000 tons per year should be a reasonable projection. The overall capital costs for the transfer stations required to collect 100,000 tons per year would thus be in the order of $1,000,000 with a corresponding amortization charge of $115,000.

It will be appreciated that it is not reasonable to assign amortization costs for transfer stations to the community serviced by the transfer station. If this were done small communities would probably find the costs prohibitive. For example, in the community of 1000, producing about 500 tons per year with a transfer station costing $20,000, the amortization charge alone would be about $4 per ton. Instead it is reasonable to assign the amortization cost of stations to the entire area benefitting from them, in this case, against the entire 150,000 tons to be treated in the central plant. Thereby, the transfer amortization charge becomes $0.77 per ton of waste treated.

It is interesting to note that the transfer station envisaged requires almost no labour for its operation. If wastes are bulldozed to compress them, if they are stock-piled in any way before loading

or even if they are stored in bins for loading into trucks, it is inevitable that some labour will be required for the operation. Thus it is not uncommon to find that operating costs for a transfer station in a major urban centre are as high as $1.50 per ton of waste.

The trade-off on transporation costs and benefits can now be determined by equating the total savings anticipated by expansion ($300,000 per year for this example) to the total amortization charge ($115,000 ) and total transportation costs. Transportation costs will be the product of mileage, tonnage hauled, and cost per ton, i.e.:

$$\text{Total Transport Cost} = M(100{,}000)\left(\frac{0.50}{20}\right)$$

where: M is the average round trip mileage for hauling the entire 100,000 tons.

Thus: $$300{,}000 = 115{,}000 + M(100{,}000)\left(\frac{0.50}{20}\right)$$

whence: $M = 74$.

It would appear, therefore, that the transportation costs for an average distance of 37 miles might be economically justified. This conclusion suggests that regional collection and central disposal systems are distinct possibilities for areas consisting of small communities.

## DISCUSSION

It is important to appreciate that a regional collection system would not be universally applicable. In particular, the system may not be applicable to areas where the individual communities are small enough for simple dumps to be tolerable. For these communities the imposition of regional disposal would increase disposal costs by substituting a more expensive disposal system and adding a transportation cost. However those costs may be acceptable to a community that wishes to eliminate its dump for aesthetic or other reasons.

In the same vein, the calculation that suggests that an average haul of 37 miles is practical is only a preliminary estimate that is intended only to indicate that collections over considerable distances are worth investigation. The conditions for this example have been chosen to illustrate the feasibility of operating a treatment

or disposal system on a regional basis. Further data, and a more detailed evaluation, are required to extend this analysis.

It is certain, however, that if a regional collection scheme can be encouraged or enforced in many areas in Ontario the problems of collection and transfer of the waste to a central operation would be solved to the benefit of the entire community.

# CHAPTER 11

## CONCLUSIONS AND RECOMMENDATIONS

The opening chapters of this report outlined the sources and magnitude of the waste disposal problem and examined the goals for the study which were to review the state of the art, to investigate the feasibility of a reclamation process and to consider the markets for reclaimed materials.

### THE STATE OF THE ART

It is found that Canada has lagged the United States both in terms of legislation and the investigation of the disposal and treatment of municipal wastes. Data on the nature and quantity of municipal wastes is not available and no methods other than the traditional means of burial or incineration have been employed in Canada. Furthermore there is no organization in Canada which currently serves as an authoritative source of knowledge; neither is there a centre of research and development in this field. The newly created Waste Management Branch in Ontario has the authority to develop and provide these services but it is so understaffed and inadequately funded that its work is almost solely concerned with the immediate and urgent problems associated with the implementation of the Waste Management Act. Such is the state of the art in Canada.

The 'art' is developing very rapidly in the United States and in other countries. Many new processes are being developed and the phenomena of solid waste generation and its implications are receiving considerable attention. This study has briefly reviewed this work and has attempted to compare the costs of different processes which might find application in Canada. A summary of the cost data derived in this study is presented in Figure 11.1.

The intent of the Ontario Air Management and Waste Management Acts has been interpreted in the strictest sense in the evaluation of potential processes. Thus it is presumed that licence

to operate dumps or incinerators without air pollution abatement equipment is a temporary act of discretion to avoid imposing intolerable hardships on small communities. Cost data for dumps and simple incinerators have therefore not been presented.

The information given in Figure 11.1 indicates that the implementation of the Waste Management Act will appreciably raise the cost of municipal waste disposal throughout the Province. This is not thought to be of serious concern since the improved methods required will only increase the overall disposal cost, which includes collection charges, by 10 to 20 percent, or by an annual amount of two to three dollars per person. However the capital requirements will be substantial and it is possible that many communities will need financial assistance in order to comply with the regulations and be able to consider methods which will provide long term solutions.

One of the most important conclusions to be made is that communities should be encouraged to develop a treatment or disposal system on a regional basis. The advantages of size in reducing the operating cost is illustrated by Figure 11.1 but the amalgamation of many small potential systems should permit the construction of a more sophisticated and better controlled treatment unit. In the larger cities the converse might be true in that smaller units, strategically situated, could reduce the overall costs. The optimization of a disposal system and the evaluation of large-scale units are beyond the scope of this study but this aspect clearly merits further attention.

The cost data presented have been based on similar initial assumptions as to the nature of the community. It should be recognized, however, that no one method can be considered to provide the ideal universal solution to the municipal waste disposal problem and the operating costs given in this study will be modified by the specific requirements of a community. Nevertheless a sanitary landfill operation will probably prove to be the simplest and least costly of all the processes which have been considered for those communities which have ready-access to a suitable and publicly acceptable land site.

The reasons why a landfill operation is undesirable and often too costly have been detailed in this study. Fortunately alternatives

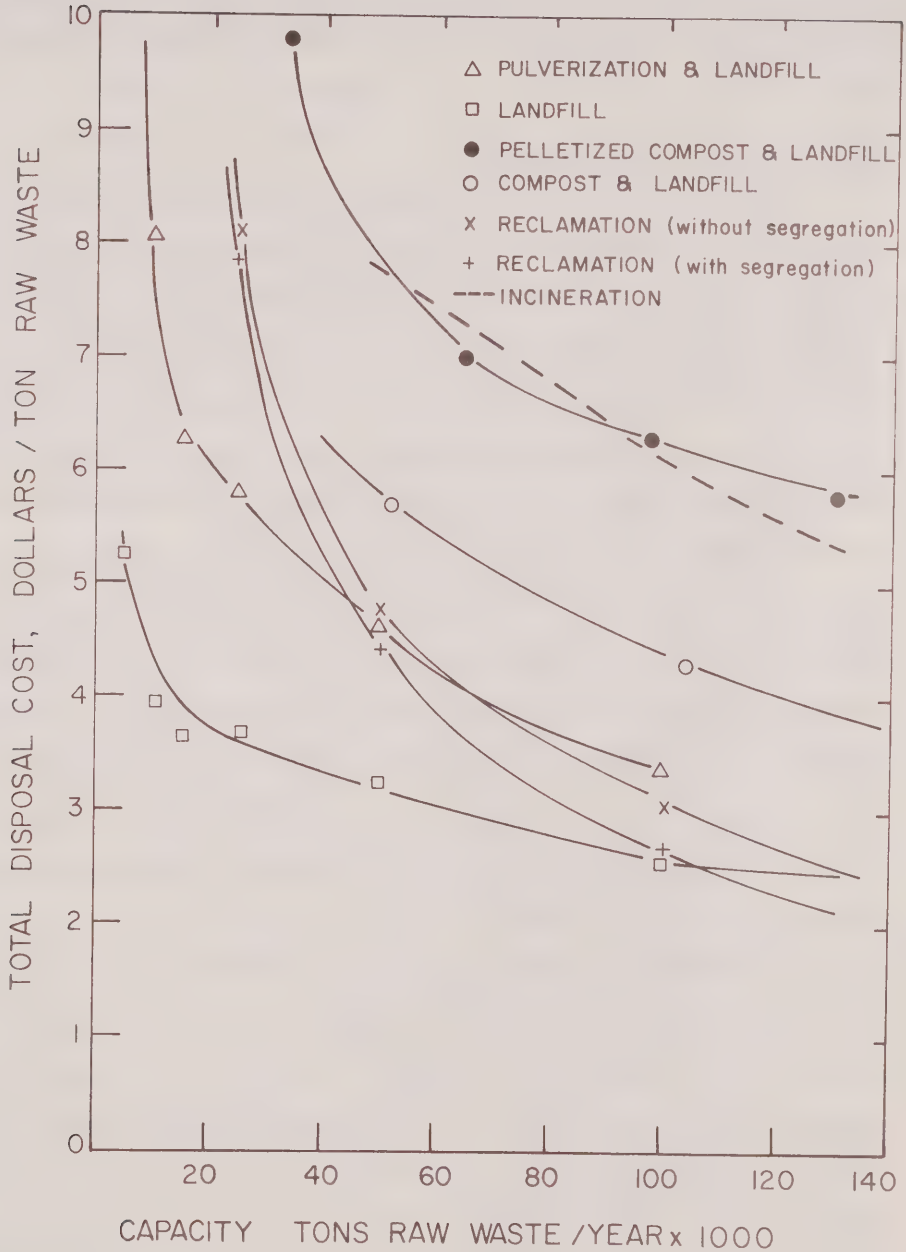



FIGURE 11.1: COST CAPACITY RELATIONSHIPS FOR VARIOUS WASTE DISPOSAL SYSTEMS

which are only marginally more expensive are available. Of these, a reclamation system would appear to hold the greatest future promise, not only as a method of treating waste but also as a means of conserving Canada's natural resources.

THE FEASIBILITY OF RECLAMATION

The goal of a feasibility study is to determine whether a project will be an economic and practical venture for a given set of specific conditions. In undertaking this analysis for a new process the natural tendency is to attempt to insure against failure by underestimating the potential returns and inflating the operating costs. The assumptions made in the evaluation of the reclamation processes illustrate this influence and may have led to an overly conservative analysis. The absence of confirmed markets for the reclaimed materials in large measure was responsible for this approach.

The economic potential of a reclamation process is high, as indicated by Figure 11.1. At capacities of 100,000 tons per year these processes are directly competitive with a sanitary landfill operation and even at 50,000 tons per year they could be competitive with sanitary landfill under certain conditions and are directly competitive with other systems such as sanitary landfill using pulverized material. In the low capacity range the costs of a reclamation process decrease so rapidly with increasing capacity that regionally operated reclamation units would seem to be desirable.

A reclamation process may offer advantages other than those revealed by a comparison of operating costs. For example a reclamation unit could be sited in any location which is suitable for a light industry. This could have a significant effect on the collection and haulage costs and would greatly assist a municipality in choosing a location. The possibility of combining a reclamation unit with the sewage disposal system could also be a deciding factor leading to the choice of a reclamation process of the form described in this study. The production of ground cover using the compost product might be of paramount importance in other localities.

A reclamation process should not incur any of the pollution

hazards associated with the traditional means of disposal. Of greater long term significance is the opportunity which is provided to conserve the natural resources and in so doing to reduce the level of pollution which is generated in the production of many materials.

Although the economy of the country has been largely dependent on the production of rapidly consumable or disposable items, changes in public attitude and government policies will inevitably occur in the next decade. The technology necessary to implement these future policies must be developed as quickly as possible and the construction of a prototype reclamation unit which can be used for research and development should be regarded as a timely if not essential investment for the future.

The desirability of constructing such a unit cannot be denied. It would enable the technology of the process to be investigated, markets to be explored, and would stimulate the investigation of new products. It would serve to provide information on the feasibility of reclamation processes in Canada and could also be used to investigate the possibilities of treating other waste materials of an industrial or commercial origin. The eventual development of an integrated unit for solid waste, sewage and water treatment is also technically feasible and could be investigated.

If the pilot unit is to serve these purposes and perhaps form the basis for a centre for waste treatment study and research it is reasonable to expect that federal and provincial government funding of the project could be justified. Further units of this kind might prove to be less expensive as a result of the knowledge gained in the operation of the pilot unit. Nevertheless reclamation units will require an initial capital investment in excess of that which is immediately available in a community and the decision between private operation and community operation aided by a government loan will need to be made. It is important, however, that the pilot unit should be operated to provide information and knowledge which can be freely made available to all communities. For this reason government funding of the prototype unit would appear to be essential to guarantee this result.

The first Canadian community to operate a reclamation system can expect to find itself a centre of interest for industries, governments and various technical organizations. If the pilot unit should receive government support there is little doubt that many communities would welcome the opportunity to take part in this development.

MARKETS FOR RECLAIMED MATERIALS

This study has not identified any new products for which any notable market might exist. Thus the existence of markets for paper, metals and rags was well known and the utility of glass as a recycle stream recognized. Furthermore the work of the glass industry, not the effort of the authors, is responsible for such other outlets for glass as have been identified.

However the study has revealed a few significant features of the markets for reclaimed materials which have not been previously identified and which will bear heavily on the development of reclamation systems. These points which warrant clear identification are as follows:

1. Unless reclamation systems are established, the prospect for generating a useful stream of reclaimed paper from municipal wastes is minimal. The paper industry requires a reliable source of reclaimed paper of standard quality in large quantities. These requirements cannot be met by the intermittent flows of reclaimed paper from current sources.
2. The quality control requirements of the paper industry could provide the incentive for the inclusion in reclamation plants of units to pulp, de-ink and screen the recovered fibre. The goal would be the production of quality-controlled fibres at the reclamation plant for sale as premium products on long-term contracts to the appropriate mills. In view of the industry's anticipated need for reclaimed paper this approach should provide a materially higher return to the reclamation plant than the direct sale of scrap and could more than justify the inclusion of the additional units.
3. Reclamation plants are essential to the development of any

significant stream of recycle glass for the glass industry from outside its own process. The current attempts of the industry to collect scrap glass by repurchasing non-returnable bottles has provided a stream of recycled glass but this stream will be small compared with that which could be obtained from reclamation processes. Glass is a common container of foods and other consumer goods and only through an effective reclamation system is this material likely to be recovered in significant quantities.

4. Many of the composting plants operated in the U.S.A. in recent years appear to have failed for economic, not technical, reasons arising from the assumption that a retail market for pelletized or baled compost could be developed. As noted by Jones[1] and others composting should be regarded primarily as a sanitizing treatment and considerable effort will be required to develop a market for compost and related products.
5. The full benefits of a reclamation system cannot be established until reclaimed materials are available in sufficient quantity to be evaluated. For example the investigation of the utility of compost and of the market potential for reclaimed paper, new products from glass, products based on reclaimed plastics and even for the amount of clean fill obtainable from municipal wastes require that a plant be operated to provide bulk materials and data for a market research study.
6. The markets for reclaimed glass and paper alone are enough to justify serious consideration of reclamation systems, not because they will allow these systems to earn a profit but because they will make their costs competitive with the costs of other systems. These markets are sufficient to ensure that the recovery operations are financially self-supporting and that as such these operations will provide employment in the community and subsidize the operation of the remainder of the disposal system.

In summary, the development of reclamation systems cannot be allowed to depend on the prior demonstration of market values for all

1. Jones, P.H. "Future and Research in Refuse Disposal" Engineering Journal, June 1969.

the products since a pilot reclamation unit is needed to generate reliable market data in order to establish product specifications and to provide materials for product development studies.

RECOMMENDATIONS

The Ontario Waste Management Act came into effect on September 1st, 1970. Many of the recommendations which might be made could be interpreted as a re-statement of this Act or of the Regulations and the Comprehensive Plan which have already been developed by the newly established Waste Management Branch of the Ontario Department of Energy and Resources.

The proposed range of activities for the Waste Management Branch includes the provision of field assistance, inspection and licensing of systems, development of an expertise, encouragement of research and development work and liaison with other government and private organizations. Whereas it is recognized that the Branch is in the development stage and that many of these activities will receive future attention, it is obvious that in comparison with similar departments in other countries the Branch is understaffed and underfinanced. Certainly the importance of this Branch is not consistent with the present budget allocations of \$43,000,000 for the Ontario Water Resources Commission, \$3,500,000 for the Air Management Branch and a mere \$209,000 for the Waste Management Branch.

The first recommendation of this study must therefore be that:

> The provincial government should ensure the effectiveness of the Waste Management Branch by making available such resources as are needed to implement the policies established by the Waste Managment Act.

It is noted that the following wastes are exempted from the Act and the subsequent Regulations of the Waste Management Branch:

1. Abandoned motor vehicles
2. Agricultural wastes
3. Condemned and dead animals
4. Hauled sewage
5. Inert fill
6. Rock fill or mill tailings from a mine.

The control of the treatment and disposal of these wastes is monitored by other departments of the provincial government. This division of responsibility is unfortunate but might be unavoidable and it is therefore recommended that:

> Immediate attention should be given to the coordination of the activities of all branches of the government concerned in the solid waste field, recognizing that integration of the processes to treat and dispose of these wastes might be achieved and that investigatory studies may have implications and benefits of common concern.

The complex nature of the solid waste problem has been described in this study but the study has necessarily been restricted to the technological aspects. The political, legal, financial, industrial and social phenomena which are involved in the problem need further consideration. Of immediate and particular concern is the determination of the means to encourage the development of regional treatment centres to serve a number of communities. The method of choosing the most suitable process and financing construction of these facilities needs to be considered. It is therefore recommended that:

> The work of the Waste Management Branch should be immediately expanded to encompass the political, legal, financial, industrial and social aspects of the solid waste problem.

The Branch has been given the authority to conduct and sponsor research and development work in the solid waste field. There is considerable evidence to believe that vast sums could be spent in academic research with little return for the investment. Furthermore, in other countries, particularly in the United States, research and the development of new processes has already established the direction for further work. It is therefore recommended that:

> Although the Branch should conduct and sponsor research and development programs, a minimum of physical research should be undertaken and such as is undertaken should have specific goals and be preceded by detailed feasibility studies

to establish the application and potential usefulness of the research.

In order to conserve financial resources and provide the degree of cooperation required between those working in various disciplines it is further recommended that:

Every attempt should be made to concentrate the research and development activities so as to provide for the eventual establishment of a centre for study and research.

Another function of the Waste Management Branch is to publish and disseminate information on the subject of waste disposal practices. If progress is to be made the public must be made aware of the real problems and the need for new approaches. In addition, those responsible for making the selection of a system for a community must be better informed on the technical, political and financial aspects. If in compliance with the new Act, decisions which commit financial resources for many years are made in haste without the necessary information, the implementation of the intent of the Act could be severely delayed. It is therefore strongly recommended that:

Data on the requirements, limitations and potentials of the various waste disposal systems should be made available to the public and to municipal officers on a continuing basis.

The Waste Management Act specifically provides the Branch with the authority to establish and operate demonstration sites. This study has shown that the entire potential of reclamation systems, whether measured in terms of economic effect, aesthetic values or conservation of material resources, depends on the generation of reliable experience in reclamation technology. It is therefore recommended that:

Appropriate prototype facilities for a reclamation process should be established in such a location that the development of the process can be fostered and studied and under such conditions that the knowledge generated can be made readily available to all communities.

Finally, if the authors were restricted to one recommendation it would need to be that:

> The current problem of solid waste disposal should be regarded as an opportunity for Canadian originality and foresight to develop the means for conserving natural resources, preserving the environment and demonstrating that organizations, communities and individuals can effectively cooperate in a common cause.

# APPENDIX A

## STATUTES AND STANDARDS

# BILL 94

3rd Session, 28th Legislature, Ontario
19 Elizabeth II, 1970

# The Waste Management Act, 1970

Mr. Kerr

TORONTO
Printed and Published by William Kinmond, Queen's Printer and Publisher

BILL 94 1970

# The Waste Management Act, 1970

HER MAJESTY, by and with the advice and consent of the Legislative Assembly of the Province of Ontario, enacts as follows:

**1.** In this Act, Interpretation

(*a*) "Advisory Board" means the Waste Management Advisory Board;

(*b*) "Appeal Board" means the Waste Management Appeal Board;

(*c*) "Department" means the Department of Energy and Resources Management;

(*d*) "Director" means the Director of the Waste Management Branch of the Department of Energy and Resources Management;

(*e*) "inspector" means a person employed or appointed to assist in the administration of this Act;

(*f*) "medical officer of health" means a medical officer of health appointed under *The Public Health Act*; R.S.O. 1960, c. 321

(*g*) "Minister" means the Minister of Energy and Resources Management;

(*h*) "municipality" includes a metropolitan municipality, a regional municipality and a district municipality;

(*i*) "operator" means the person in occupation or having the charge, management, or control of a waste management system or a waste disposal site;

(*j*) "owner" means a person or municipality that owns or is responsible for the establishment or direction of a waste management system or a waste disposal site;

(*k*) "regulations" means the regulations made under this Act;

(*l*) "waste" includes ashes, garbage, refuse, domestic waste, industrial waste, or municipal refuse and such other wastes as are designated in the regulations;

(*m*) "waste disposal site" means any land or land covered by water upon which, or building or structure in which, waste is deposited or processed and any machinery or equipment or operation required for the treatment or disposal of waste;

(*n*) "waste management system" means all facilities, equipment and operations for the complete management of waste, including the collection, handling, transportation, storage, processing and disposal thereof, and may include one or more waste disposal sites.

Application of Act

**2.** This Act does not apply to the storage or disposal by any person of his domestic wastes on his own property unless in the opinion of the Minister such storage or disposal may create a nuisance or to any sewage or other works to which *The Ontario Water Resources Commission Act* or the regulations thereunder apply.

R.S.O. 1960, c. 281

Authority of Minister

**3.** The Minister, for the purposes of the administration and enforcement of this Act and the regulations, may,

(*a*) investigate waste management problems;

(*b*) conduct research in the field of waste management;

(*c*) establish and operate demonstration and other waste disposal sites;

(*d*) publish and disseminate information on waste management;

(*e*) make grants for research, for training persons in the field of waste management, or for the development of waste management facilities, in such amounts and upon such terms and conditions as the regulations may prescribe;

(*f*) appoint committees to perform such advisory functions as the Minister considers desirable.

Authorization by Minister

**4.** The Minister may authorize any officer or officers of the Department to exercise any of the powers conferred and perform any of the duties imposed upon him under this Act and the regulations.

**5.**—(1) The Minister may designate officers of the Department or other persons as inspectors for the purposes of this Act and the regulations. Inspectors

(2) A medical officer of health shall be deemed to be *ex officio* an inspector under this Act. Idem

**6.** An inspector may enter in or upon any land or premises, other than a dwelling, at any reasonable time and make or require to be made such examinations, tests, or inquiries as may be necessary or advisable for the purposes of this Act and the regulations. Powers of inspector

**7.** Every operator and every owner shall furnish such information as an inspector requires for the purposes of this Act and the regulations. Information to be furnished

**8.** No person shall hinder or obstruct any inspector in the performance of his duties or furnish any inspector with false information or refuse to furnish him with information. Obstruction of inspector

**9.**—(1) A board to be known as the Waste Management Advisory Board is hereby established and shall consist of not fewer than five persons appointed by the Lieutenant Governor in Council, of whom none shall be members of the public service in the employ of the Department of Energy and Resources Management or members of the Appeal Board, and who shall, subject to subsection 2, hold office during pleasure. Waste Management Advisory Board established

(2) No member of the Advisory Board shall hold office for more than five consecutive years. Term of office

(3) The Lieutenant Governor in Council may appoint one of the members of the Advisory Board as chairman and another of the members as vice-chairman. Chairman and vice-chairman

(4) Three members of the Advisory Board constitute a quorum. Quorum

(5) The members of the Advisory Board shall be paid such remuneration and expenses as the Lieutenant Governor in Council from time to time determines. Remuneration

**10.**—(1) A board to be known as the Waste Management Appeal Board is hereby established and shall consist of not fewer than five persons appointed by the Lieutenant Governor in Council, of whom none shall be members of the public service in the employ of the Department of Energy and Resources Management or members of the Advisory Board, and who shall, subject to subsection 2, hold office during pleasure. Waste Management Appeal Board established

Term of office

(2) No member of the Appeal Board shall hold office for more than five consecutive years.

Chairman and vice-chairman

(3) The Lieutenant Governor in Council may appoint one of the members of the Appeal Board as chairman and another of the members as vice-chairman.

Quorum

(4) Three members of the Appeal Board constitute a quorum.

Remuneration

(5) The members of the Appeal Board shall be paid such remuneration and expenses as the Lieutenant Governor in Council from time to time determines.

Certificate of approval, etc.

**11.** No waste management system that is in operation or waste disposal site that is in use when this Act comes into force shall be operated or used,

(*a*) for more than six months after this Act comes into force unless the owner has made application for a certificate of approval;

(*b*) after a certificate of approval has been refused; or

(*c*) where a certificate of approval or provisional certificate of approval has been issued, except in accordance with the terms and conditions of such certificate.

New systems and sites and extensions, etc.

**12.** No person or municipality shall establish, alter, enlarge or extend,

(*a*) a waste management system; or

(*b*) a waste disposal site,

unless a certificate of approval or provisional certificate of approval therefor has been issued by the Minister.

No money by-law without certificate

**13.** No by-law for raising money to finance any work under section 11 shall be passed by the council of a municipality until a certificate of approval or a provisional certificate of approval has been issued therefor.

Municipal responsibility

**14.** Where the Minister reports in writing to the clerk of a municipality that he is of the opinion that it is necessary in the public interest that waste be collected or a waste management system or any part thereof be established, maintained, operated, improved, extended, enlarged, altered, repaired or replaced, it is not necessary to obtain the assent

of the electors to any by-law for incurring a debt for any such purpose, and the municipality shall forthwith do every possible act and thing in its power to implement the report of the Minister within the time specified.

**15.** No certificate of approval shall be issued to an applicant other than a municipality unless the applicant has, Condition precedent to issue of certificate

(*a*) deposited a sum of money; or

(*b*) furnished a surety bond; or

(*c*) furnished personal sureties,

in such amount and upon such conditions as the regulations prescribe to assure satisfactory maintenance of the waste management system or the waste disposal site or the removal of waste from the site if the Minister considers such removal necessary.

**16.** No certificate of approval for a waste disposal site shall be issued to an applicant other than a municipality unless the applicant has furnished a certificate from the municipality in which the waste disposal site is situated that the waste disposal site does not contravene any of the by-laws of the municipality. Certificate of municipality required

**17.** The deposit mentioned in clause *a* of section 15 may be returned to the depositor upon such terms and conditions as the regulations prescribe. Return of deposit

**18.** An applicant for a certificate of approval for a waste management system or waste disposal site that it is proposed to establish, alter, enlarge or extend shall publish notice of his application in a newspaper having general circulation in the locality where the system or site is or is to be located, once a week for three successive weeks, and no certificate of approval shall be issued until the expiration of three weeks from the date of the last publication. Publication of notice of application

**19.** An applicant for a certificate of approval shall submit to the Director plans and specifications of the work to be undertaken together with such other information as the Director may require. Information to be furnished

**20.**—(1) The Director, after considering an application for a certificate of approval, may recommend to the Minister that a certificate of approval or provisional certificate of approval be issued. Recommendation by Director

Idem

(2) The Director may recommend to the Minister that the issue or renewal of a certificate of approval or a provisional certificate of approval be refused, or that a certificate of approval or a provisional certificate of approval previously issued be suspended or revoked, where,

(*a*) the application does not comply with this Act and the regulations;

(*b*) the waste management system or the waste disposal site does not comply with this Act and the regulations; or

(*c*) the operation of the waste management system or the waste disposal site may create a nuisance or is not in the public interest or, in the opinion of the medical officer of health, may result in a hazard to public health.

Prohibition as to deposit of waste

**21.** Subject to section 11, no person or municipality shall deposit waste upon any land or land covered by water or in any building that is not a waste disposal site for which a certificate of approval or a provisional certificate of approval has been issued and except in accordance with the terms and conditions of such certificate.

Prohibition as to use of facilities, etc.

**22.** Subject to section 11, no person or municipality shall use any facilities or equipment for the storage, handling, treatment, collection, transportation, processing or disposal of waste that is not part of a waste management system for which a certificate of approval or a provisional certificate of approval has been issued and except in accordance with the terms and conditions of such certificate.

Order for removal of waste

**23.**—(1) Where the Director reports that waste has been deposited upon any land or land covered by water or in any building that has not been approved as a waste disposal site, the Minister may, subject to sections 11 and 26, order the occupant or the person having charge and control of such land or building to remove the waste and to restore the site to a condition satisfactory to the Minister.

Action upon failure to comply with order

(2) Where a person to whom an order is directed under subsection 1 fails to comply with the order, the Minister may cause the necessary work to be done and charge such person with the cost thereof, which may be recovered with costs in any court of competent jurisdiction.

Order by Minister

**24.** Where the Director reports to the Minister that a waste management system or a waste disposal site is not in conformity with this Act or the regulations, the Minister may,

subject to section 26, order the owner to take such action as he may require to bring the system or the site into conformity with this Act or the regulations within the time specified in the order.

**25.** Where an owner fails to comply with an order under section 24, the Minister may cause the necessary work to be done and charge the owner with the cost thereof which, in the case of an owner other than a municipality, may be deducted from the deposit mentioned in section 15, or may be recovered with costs in any court of competent jurisdiction. Action upon non-compliance with order

**26.**—(1) Where the Minister, Where Minister intends to make order, etc.

(*a*) intends to refuse to issue or renew or intends to suspend or revoke a certificate of approval or provisional certificate of approval; or

(*b*) intends to make an order under section 23 or 24,

he shall cause the Director to give notice of his intention, together with the reasons therefor, and a notice stating the right to a hearing before the Advisory Board, to the owner or the person to whom the order would be directed, as the case may be, and the owner or such person may by written notice given to the Director and the Advisory Board within fifteen days after receipt of notice from the Director, receive a hearing by the Advisory Board.

(2) The chairman of the Advisory Board shall fix a time, date and place for the hearing and shall serve notice on the parties at least ten days before the day fixed. Notice of hearing

(3) The notice of hearing shall contain, Contents of notice

(*a*) a statement of the time, date and place of the hearing;

(*b*) a reference to the rules of procedure applicable to the hearing; and

(*c*) a statement that, if a party who has been duly notified does not attend at the hearing, the Advisory Board may proceed in his absence and he is not entitled to notice of any further proceedings.

(4) The Director, any person who receives a notice from the Director under subsection 1, and any other person specified by the Advisory Board, are parties to the hearing. Parties

Failure to attend

**27.**—(1) If a person who has been duly notified of a hearing does not attend, the Advisory Board may proceed in his absence and he is not entitled to notice of any further proceedings.

Adjournment

(2) A hearing may be adjourned from time to time by the Advisory Board on reasonable grounds,

(*a*) on its own motion; or

(*b*) on the motion of any party to the hearing.

Subpoena

(3) The Advisory Board may command the attendance before it of any person as a witness.

Oaths and affirmations

(4) The Advisory Board may require any person,

(*a*) to give evidence on oath or affirmation at a hearing; and

(*b*) to produce such documents and things as the Advisory Board requires.

Idem

(5) The Advisory Board may admit evidence not given on oath or by affirmation.

Evidence

**28.**—(1) At a hearing before the Advisory Board,

(*a*) except where otherwise provided in this subsection, the common law and statutory rules of evidence apply;

(*b*) evidence not admissible under clause *a* may be admitted by the Advisory Board in its discretion if to do so may expedite the hearing and will not prejudice any party; and

(*c*) the Advisory Board may admit evidence in the form of a copy or an excerpt of a document if the document itself is not readily available.

Release of exhibits

(2) Documents and things put in evidence at a hearing shall, upon the request of the person who produced them, be released to him by the Advisory Board within a reasonable time after the matter in issue has been finally determined.

Offence

**29.**—(1) Any person who, without lawful excuse,

(*a*) on being duly summoned as a witness before the Advisory Board, makes default in attending; or

(*b*) being in attendance as a witness before the Advisory Board, refuses to take an oath legally required by the Advisory Board to be taken, or to produce any documents or things in his power or control legally required by the Advisory Board to be produced by him, or to answer any question to which the Advisory Board may legally require an answer; or

(*c*) does any other thing that would, if the Advisory Board had been a court of law having power to commit for contempt have been contempt of that court,

is guilty of an offence.

(2) The Advisory Board may certify an offence under subsection 1 to the High Court and that court may thereupon inquire into the offence and after hearing any witnesses who may be produced against or on behalf of the person charged with the offence, and after hearing any statement that may be offered in defence, punish or take steps for the punishment of that person in like manner as if he had been guilty of contempt of that court. Enforcement

**30.**—(1) Any party may be represented before the Advisory Board by counsel or agent. Right of party to counsel

(2) Any witness may be represented before the Advisory Board by counsel or agent, but at the hearing the counsel or agent may only advise the witness and state objections under the provisions of the relevant law. Right of witness to counsel

(3) Where a hearing is *in camera*, a counsel or agent for a witness shall be excluded except when that witness is giving evidence. Exclusion of counsel or agent

**31.**—(1) Any party who is present at a hearing before the Advisory Board may call and examine his witnesses, cross-examine opposing witnesses and present his arguments and submissions. Rights of parties

(2) All hearings shall be open to the public except where the Advisory Board finds that, Hearings to be open to public, exceptions

(*a*) public security may be involved; or

(*b*) intimate financial or personal circumstances of any person or any secret manufacturing or trade process may be disclosed,

in which case the Advisory Board shall hold the hearing as to any such matters *in camera*.

Idem

(3) Notwithstanding the exceptions mentioned in clauses *a* and *b* of subsection 2, the Advisory Board may, if in its opinion the public interest so requires, proceed without regard to such exceptions.

Recommendations to Minister by Board

**32.**—(1) The Advisory Board shall, after the hearing, submit to the Minister in writing its recommendations, including the reasons therefor, and shall furnish the Minister with a copy of the evidence submitted at the hearing.

Reasons for recommendations

(2) The reasons for the Advisory Board's recommendations shall contain,

(*a*) the findings of fact on the evidence and any information or knowledge used in reaching the decision;

(*b*) any agreed findings of fact; and

(*c*) any conclusions of law based on the findings mentioned in clauses *a* and *b*.

Notice of recommendations

(3) The Advisory Board shall serve each party with a copy of its recommendations together with the reasons therefor.

Powers of Minister

**33.**—(1) Upon receipt of the recommendations of the Advisory Board, the Minister may issue or renew, or refuse to issue or renew, or suspend or revoke a certificate of approval, or a provisional certificate of approval, or may make such order under section 23 or 24, as the case may be, as he considers necessary.

Notice of decision

(2) A notice of the decision of the Minister and a notice stating the right, if any, to apply for compensation under section 34 shall be served on each party either personally or by registered mail addressed to the party at his last known address.

Right to compensation

**34.**—(1) Within thirty days after the receipt of notice of the decision that the Minister has refused to renew or has suspended or revoked a certificate of approval, any owner who has suffered pecuniary loss as a result of such decision affecting his waste disposal site or waste management system may apply to the Minister for compensation for such loss where such owner,

(*a*) has received a certificate of approval for the waste disposal site or waste management system affected by the Minister's decision; and

(*b*) since receiving such certificate of approval, has strictly complied with this Act and the regulations.

(2) A notice of the decision of the Minister in disposing of the application and a notice stating the right to an appeal under this section shall be served on the owner either personally or by registered mail addressed to the owner at his last known address. Notice of decision and right to appeal

(3) Within fifteen days after receipt of the notices referred to in subsection 2, the owner may appeal the amount of compensation, if any, to the Appeal Board, and such appeal shall be a hearing *de novo* and the Appeal Board may dismiss the appeal or alter the decision of the Minister establishing the amount of the compensation, if any, and the decision of the Appeal Board shall be final. Right to appeal

(4) Subsections 2, 3 and 4 of section 26 and sections 27, 28, 29, 30 and 31 apply *mutatis mutandis* to a hearing before the Appeal Board. Application of certain sections

(5) The Appeal Board shall, after the hearing, submit to the Minister and the appellant its decision in writing and shall furnish the Minister with a copy of the evidence submitted at the hearing. Decision of Appeal Board

(6) The reasons for the Appeal Board's decision shall contain, Reasons for decision

(*a*) the findings of fact on the evidence and any information or knowledge used in reaching the decision;

(*b*) any agreed findings of fact; and

(*c*) any conclusions of law based on the findings mentioned in clauses *a* and *b*.

(7) The Appeal Board shall serve each party with a copy of its decision together with the reasons therefor. Copy of decision to be served

(8) After receipt of the decision of the Appeal Board, the Minister shall do what is necessary to give effect thereto. Minister to take necessary action

**35.** No use shall be made of land or land covered by water which has been used for the disposal of waste within a period of twenty-five years from the year in which such land ceased to be so used unless the approval of the Minister for the proposed use has been given. Former disposal sites

**36.** Every person or municipality that contravenes any provision of this Act or the regulations or fails to comply with an order made under section 23 or 24 is guilty of an Offences

offence and on summary conviction is liable to a fine of not less than $100 and not more than $2,000 for every day or part thereof upon which such offence occurs or continues.

Regulations

**37.** The Lieutenant Governor in Council may make regulations,

(*a*) designating wastes in addition to those specified in clause *l* of section 1, and exempting any wastes from this Act and the regulations or any provision thereof, and prescribing terms and conditions for such exemption;

(*b*) classifying waste management systems and waste disposal sites, and exempting any class thereof from this Act or the regulations or any provision thereof, and prescribing terms and conditions for such exemption;

(*c*) providing for the issue of certificates of approval and provisional certificates of approval for waste management systems or waste disposal sites, or any class thereof, prescribing terms and conditions upon which such certificates may be issued, and providing for determining the terms and conditions that may be attached thereto;

(*d*) governing and regulating the management of waste and prescribing standards for waste management systems and for the location, maintenance and operation of waste disposal sites, or any class thereof;

(*e*) governing the location of waste disposal sites and designating parts of Ontario in which no waste disposal sites, or any class thereof, shall be established or operated;

(*f*) prescribing the amounts and conditions of deposits and bonds and sureties for the purpose of section 15, and prescribing the terms and conditions upon which deposits may be returned under section 17;

(*g*) prescribing the records that shall be kept by operators of waste management systems and waste disposal sites and the reports that shall be made by such operators;

(*h*) prescribing the amounts and terms and conditions of grants payable to universities and other organizations under clause *e* of section 3;

(*i*) prescribing the form of application and the procedure to be followed in applying for any compensation under this Act;

(*j*) respecting any matter necessary or advisable to carry out effectively the intent and purpose of this Act or the regulations.

**38.** This Act comes into force on the 1st day of September, 1970. Commencement

**39.** This Act may be cited as *The Waste Management Act, 1970.* Short title

# BILL 94

The Waste Management Act, 1970

*1st Reading*

May 21st, 1970

*2nd Reading*

June 9th, 1970

*3rd Reading*

June 25th, 1970

MR. KERR

1970

REGULATION MADE UNDER
THE WASTE MANAGEMENT ACT, 1970

GENERAL

INTERPRETATION

1. In this Regulation,

1. "abandoned motor vehicle" means a motor vehicle abandoned on public or private property and includes such part of a motor vehicle that is left after salvaging;

2. "access road" means a road that leads from a public road to a waste disposal site;

3. "agricultural waste" means waste, other than sewage, resulting from farm operations, including animal husbandry and where a farm operation is carried on in respect of food packing, food preserving, animal slaughtering or meat packing, includes the waste from such operations;

4. "cell", in respect of a landfilling site, means a deposit of waste that has been sealed by cover material so that no waste disposited in the cell is exposed to the atmosphere;

5. "composting" means the treatment of waste by aerobic decomposition of organic matter by bacterial action for the production of stabilized humus;

6. "cover material" means soil or other material approved for use in sealing cells in landfilling;

7. "dead animal" means an animal that dies naturally or from disease or by reason of accident and includes parts thereof;

8. "dump" means a waste disposal site where waste is deposited without cover material being applied at regular intervals;

9. "fly-ash" means particulate matter removed from combustion flue gases;

10. "grinding" means the treatment of waste by uniformly reducing the waste to particles of controlled maximum size;

11. "hauled liquid industrial waste" means liquid waste, other than hauled sewage, that results from industrial processes or manufacturing or commercial operations and that is transported in a tank or other container for treatment or disposal, and

includes sewage residue from sewage works that are subject to the provisions of The Ontario Water Resources Commission Act;

12. "hauled liquid and hazardous waste collection system" means a waste management system or any part thereof for the collection, handling, transportation, storage or processing of hauled liquid industrial waste or hazardous waste but does not include the disposal thereof;

13. "hauled sewage" means waste removed from;

    i. a cesspool,
    ii. a septic tank system,
    iii. a privy-vault or privy pit,
    iv. a chemical toilet,
    v. a portable toilet, or
    vi. a sewage holding tank at a marina,

    and transported in a tank or other container for treatment or disposal other than at a waste disposal site;

14. "hazardous waste" means waste that requires special precautions in its storage, collection, transportation, treatment or disposal, to prevent damage to persons or property and includes explosive, flammable, volatile, radio-active, toxic and pathological waste;

15. "incineration" means the treatment of waste by controlled burning, including measures for limiting air pollution, to reduce the volume of the waste and to leave it in a more stable form for disposal;

16. "incinerator ash" means the ash residue, other than fly-ash, resulting from incineration where the waste is reduced to ashes containing by weight less than 10 percent of combustible materials;

17. "incinerator waste" means the residue from incineration, other than incinerator ash and fly-ash;

18. "inert fill" means earth or rock fill that contains no putrescible materials or soluble or decomposable chemical substances;

19. "individual collection system" means the collection of his own domestic wastes by a householder and the transportation of such wastes to a waste disposal site by the householder;

20. "landfilling" means the disposal of waste by deposit, under controlled conditions, on land or on land covered by water, and includes compaction of the waste into a cell and covering the waste with cover materials at regular intervals;

21. "marine craft waste disposal system" means a waste disposal system operated by a person or a municipality for the receiving of waste from marine craft for deposit in holding tanks;

22. "municipal waste management system" means a waste management system, or any part thereof, of which a municipality is the owner;

23. "on-site garbage grinder" means a grinder,

    i. used for the treatment of waste that is subsequently discharged as sewage, and
    ii. located in a building or structure used principally for functions other than waste management;

24. "on-site road" means a road for the movement of vehicles and equipment within a waste disposal site;

25. "on-site incinerator" means an incinerator that is located in a building or structure used principally for functions other than management;

26. "packing and baling" means the treatment of waste by its compression into blocks or bales and binding or sheathing the blocks or bales with wire, metal, plastic or other material;

27. "private waste management system" means a waste management system, or any part thereof, of which a person other than a municipality is the owner;

28. "scavenging" means the uncontrolled removal of re-usable material from waste at a waste disposal site;

29. "transfer station" means a waste disposal site used for the purpose of transferring waste from a collection vehicle to another carrier for transportation to another waste disposal site.

DESIGNATION AND EXEMPTION OF WASTES

2. The following are designated wastes:

    1. Abandoned motor vehicles

    2. Agricultural wastes

    3. Condemned animals or parts thereof at a plant licensed under The Meat Inspection Act (Ontario), 1962-63 or an establishment operating under the Meat Inspection Act (Canada).

    4. Dead Animals

5. Hauled liquid industrial waste
6. Hauled sewage
7. Hazardous waste
8. Incinerator waste
9. Inert fill
10. Rock fill or mill tailings from a mine

3. The following wastes are exempted from the Act and this Regulation.

1. Abandoned motor vehicles
2. Agricultural wastes
3. Condemned animals or parts thereof at a plant licensed under The Meat Inspection Act (Ontario), 1962-63 or an establishment operating under the Meat Inspection Act (Canada).
4. Dead animals to which The Dead Animal Disposal Act applies
5. Hauled sewage
6. Inert fill
7. Rock fill or mill tailings from a mine

CLASSIFICATION AND EXEMPTION OF WASTE DISPOSAL SITES

4. Waste disposal sites are classified as follows:

1. Composting sites
2. Dumps
3. Grinding sites
4. Incineration sites
5. Landfilling sites
6. On-site incinerators
7. On-site garbage grinders
8. Packing and baling sites
9. Transfer stations

5. The following waste disposal sites are exempted from the Act and this Regulation:

1. On-site incinerators
2. On-site garbage grinders

CLASSIFICATION AND EXEMPTION OF WASTE MANAGEMENT SYSTEMS

6. Waste management systems are classified as follows:

   1. Municipal waste management systems
   2. Private waste management systems
   3. Individual collection systems
   4. Hauled liquid and hazardous waste collection systems
   5. Marine craft waste disposal systems.

7. The following waste management systems are exempted from the Act and this Regulation:

   1. Individual collection systems
   2. Marine craft waste disposal systems

CERTIFICATES OF APPROVAL FOR WASTE DISPOSAL SITES AND WASTE MANAGEMENT SYSTEMS

8. A certificate of approval for a waste disposal site or a waste management system or a renewal thereof expires one year after the date upon which the certificate or renewal is issued.

9. A provisional certificate of approval for a waste disposal site or a waste management system or a renewal thereof expires on the date shown thereon.

STANDARDS FOR WASTE DISPOSAL SITES

10.-(1) The following are prescribed as standards for the location, maintenance and operation of a landfilling site that are to be met to the satisfaction of the Minister by an applicant for a certificate of approval therefor:

   1. Access roads and on-site roads shall be provided so that vehicles hauling waste to and on the site may travel readily on any day under all normal weather conditions.

   2. Access to the site shall be limited to such times as an attendent is on duty and the site shall be restricted to use by persons authorized to deposit waste in the fill area.

   3. Drainage passing over or through the site shall not adversely affect adjoining property and natural drainage shall not be obstructed.

   4. Drainage that may cause pollution shall not, without adequate treatment, be discharged into watercourses.

   5. Waste shall be placed sufficiently above or isolated from the maximum water table at the site in such manner that impairment of groundwater in aquifers is prevented and sufficiently

distant from sources of potable water supplies so as to prevent contamination of the water, unless adequate provision is made for the collection and treatment of leachate.

6. Where required by the Minister, adequate measures to prevent water pollution shall be taken by the construction of berms and dykes of low permeability to isolate the site and effectively prevent the egress of pollutants.

7. Where required by the Minister, samples shall be taken and tests made to measure the extent of egress of pollutants and such measures as are required by the Minister shall be taken for the collection and treatment of pollutants and for the prevention of water pollution.

8. The site shall be located a reasonable distance from any cemetery.

9. Adequate and proper equipment shall be provided for the compaction of waste into cells and the covering of the cells with cover material.

10. Where climatic conditions may prevent the use of the site at all times, provision shall be made for another waste disposal site which can be used during such periods.

11. Where required for accurate determination of input of all wastes by weight, scales shall be provided at the site or shall be readily available for use.

12. All waste disposal operations at the site shall be adequately and continually supervised.

13. Waste shall be deposited in an orderly manner in the fill area, compacted adequately, and covered by cover material by a proper landfilling operation.

14. Procedures shall be established for the control of rodents or other animals and insects at the site.

15. Procedures shall be established, signs posted and safeguards maintained for the prevention of accidents at the site.

16. The waste disposal area shall be enclosed to prevent entry by unauthorized persons and access to the property shall be by roadway closed by a gate capable of being locked.

17. A green belt or neutral zone shall be provided around the site and the site shall be adequately screened from public view.

18. Whenever any part of a fill area has reached its limit of fill, a final cover of cover material shall be placed on the

completed fill and such cover shall be inspected at regular intervals over the next ensuing period of two years and where necessary action shall be taken to maintain the integrity and continuity of the cover materials.

19. Scavenging shall not be permitted.

-(2) A certificate of approval for a landfilling site is subject to the condition that the site shall continue to be maintained and operated in accordance with the standards approved therefor.

11.-(1) The following are prescribed as standards for the location, maintenance and operation of an incineration site that are to be met to the satisfaction of the Minister by an applicant for a certificate of approval therefor:

1. The location of the incineration site shall be selected so as to reduce the effects of nuisances, such as dust, noise, and traffic.

2. Incinerator waste shall be disposed of at a landfilling site.

3. The incinerator shall be located

   (a) so that it is accessible for the transportation of wastes thereto without nuisance;

   (b) taking into account meteorological considerations to minimize environmental effects; and

   (c) so that the services and utilities required for the operation of the incinerator are available, including facilities for the disposal of residue and of quenching and scrubbing water.

4. The design and capacity of the incinerator shall be in accordance with accepted engineering practices and of a type and size adequate to efficiently process the quantities of waste that may be expected, so that a minimum volume of residue is obtained, the putrescible materials remaining as residue are reduced to a minimum and a minimum of air pollution results.

5. The following equipment shall be provided as required for particular applications to the satisfaction of the Minister:

   i. Scales for the accurate determination of the input of all wastes by weight.
   ii. A storage pit or other storage facilities.
   iii. A crane or other means of removing waste from the pit or other storage facilities.
   iv. Means of controlling dusts and odours.

v. Such instruments as may be necessary for the efficient operation of an incinerator.

6. The incineration site shall include an unloading area properly enclosed and of sufficient size for the intended operation.

7. Access roads shall be provided for vehicles hauling waste to the incineration site.

8. On-site fire protection shall be provided and, where possible, arrangements shall be made with a fire department or municipality for adequate fire fighting services in case of an emergency.

9. Scavenging shall not be permitted.

-(2) A certificate of approval for an incineration site is subject to the condition that the site shall continue to be maintained and operated in accordance with the standards approved therefor.

12.-(1) The following are prescribed as the standards for the location, maintenance and operation of a dump that are to be met to the satisfaction of the Minister by an applicant for a certificate of approval therefor:

1. The fill area shall not be subject to flooding and shall be so located that no direct drainage leads to a watercourse.

2. The site shall be at least two hundred yards from the nearest public road.

3. The site shall be at least one-quarter of a mile from the nearest dwelling.

4. The site shall be at least 100 feet from any watercourse, lake or pond.

5. The site shall not be on land covered by water.

6. Signs shall be posted stating requirements for the operation of the dump, including measures for the control of vermin and insect infestation.

7. The site shall be so located and operated as to reduce to a minimum the hazards resulting from fire.

8. The operator of the dump shall apply such cover material at such intervals as the Medical Officer of Health may direct.

9. Scavenging shall not be permitted.

-(2) A certificate of approval for a dump is subject to the condition that the dump shall continue to be maintained and operated in accordance with the standards approved therefor.

13.-(1) Subject to subsection 2, no dump shall be established or operated in a city, borough, town, separated, town, township, village or police village in any county, regional municipality or the Provisional County of Haliburton.

-(2) Notwithstanding subsection 1, a dump may be established in the following parts of Ontario:

1. The townships of Albemarle, Eastnor, Lindsay and St. Edmunds, in the County of Bruce.

2. The townships of Barrie, Bedford, Clarendon, and Miller, Howe Island, Kennebec, Olden and Palmerston and North and South Canonto, in the County of Frontenac.

3. The townships of Bangor, Wicklow and McClure, Carlow, Dungannon, Elzevir and Grimsthorpe, Herschel, Limerick, Madoc, Marmora and Lake, Mayo, Monteagle, Tudor and Cashel, and Wollaston, in the County of Hastings.

4. The townships of Dalhousie and North Sherbrooke, Darling, Lavant, North Burgess, and South Sherbrooke, in the County of Lanark.

5. The townships of Asphodel, Belmont and Methuen, Chandos, Ennismore, Galway and Cavendish, and Harvey, in the County of Peterborough.

6. The townships of Bagot and Blithfield, Brougham, Brudenell and Lyndock, Groffith and Matawatchan, Head, Clara and Maria, North Algona, Radcliffe, Raglan, Sebastopol, and South Algona, in the County of Renfrew.

7. The townships of Carden, Dalton, and Laxton, Digby and Longford, in the County of Victoria.

8. The Improvement District of Bicroft, the townships of Anson, Hindon and Minden, Cardiff, Dysart, Bruton, Clyde, Dudley, Eyre, Guilford, Glamorgan, Lutterworth, Monmouth, Sherborne, McClintock, Livingstone, Lawrence and Nightingale, and Snowdon and Stanhope, in the Provisional County of Haliburton.

-(3) No dump shall be established or operated in the following parts of the territorial districts of Ontario:

1. The City of Sault Ste. Marie, the towns of Blind River, Bruce Mines, and Tessalon, the villages of Hilton Beach and Iron Bridge, and the township of Elliot Lake, in the Territorial

District of Algoma.

2. The towns of Cochrane, Hearst, Iroquois Falls, Kapuskasing, Matheson, Smooth Rock Falls, and Timmins, and the townships of Glackmeyer, Mountjoy, Tisdale and Whitney, in the Territorial District of Cochrane.

3. The towns of Dryden, Keewatin, Kenora, and Sioux Lookout, and the townships of Jaffray and Melick, in the Territorial District of Kenora.

4. The towns of Gore Bay and Little Current, in the Territorial District of Manitoulin.

5. The towns of Bala, Bracebridge, Gravenhurst, and Huntsville, and the villages of Port Carling, Port Sydney and Windermere, in the Territorial District of Muskoka.

6. The City of North Bay, the towns of Bonfield, Cache Bay, Mattawa, and Sturgeon Falls, and the townships of East Ferris, Field and Springer, in the Territorial District of Nipissing.

7. The towns of Kearney, Parry Sound, Powassan and Trout Creek, the villages of Burk's Falls, Magnetawan, Rosseau, South River and Sundridge, and the townships of Foley, McDougall, North Himsworth, and South Himsworth, in the Territorial District of Parry Sound.

8. The towns of Fort Frances and Rainy River, and the township of Atikokan, in the Territorial District of Rainy River.

9. The City of Sudbury, the towns of Capreol, Coniston, Copper Cliff, Espanola, Levack, Lively, Massey and Webbwood, and the townships of Balfour, Falconbridge, and Neelon and Garson, in the Territorial District of Sudbury.

10. The City of Thunder Bay, the Town of Geraldton and the townships of Neebing, Nipigon, Oliver, Paipoonge, Schrieber, Shuniah, and Terrace Bay, and the improvement districts of Beardmore, Manitouwadge, Nakina, and Red Rock, in the Territorial District of Thunder Bay.

11. The towns of Charlton, Cobalt, Englehart, Haileybury, Latchford, and New Liskeard, the Village of Thornloe, and the townships of Armstrong, Bucke, Larder Lake, McGarry, and Teck, in the Territorial District of Timiskaming.

STANDARDS FOR WASTE MANAGEMENT SYSTEMS

14.-(1) The following are standards for the operation of a waste management system that are to be met to the satisfaction of the Minister by an applicant for a certificate of approval therefor:

1. All waste collection vehicles and waste carriers shall be so constructed as to enable waste to be transferred safely and without nuisance from storage containers to the vehicle.

2. Bodies of waste collection vehicles and waste carriers shall be so constructed as to withstand abrasion and corrosion from the waste.

3. Bodies of waste collection vehicles and waste carriers shall be leakproof and covered where necessary to prevent the emission of offensive odours, the falling or blowing of waste material from the vehicles or the release of dust or other air-borne materials that may cause air pollution.

-(2) A certificate of approval for a waste management system is subject to the condition that the system shall continue to be operated in accordance with the standards approved therefor.

ONTARIO DEPARTMENT OF ENERGY AND RESOURCES MANAGEMENT
WASTE MANAGEMENT BRANCH

Tentative Waste Disposal Engineering Standards

Sanitary Landfill Standards

Section 1 - Design

1. Maps - The design data of the proposed sanitary landfill shall include one or more topographic maps at a scale of not over 200 feet to the inch with 5-foot contour intervals. These maps and accompanying data shall indicate the following: - The proposed fill area; any borrow area; access road; on-site road; grades for proper drainage of each cell required and a typical cross-section of a cell; special drainage devices if necessary; fencing; any structures on the site shall be shown, existing and proposed utilities; and all other pertinent information to clearly indicate the soil characteristics, watertable, orderly development, operation, and completion of the sanitary landfill. A land use plan of the adjacent areas may be required. The detail of the buffer zone will be shown. The routes proposed for hauling from collection areas will be presented.

2. Geology - The geological characteristics of the proposed site shall be determined by on-site testing or from earlier reliable survey data to indicate soil surveys, water tables and subsurface characteristics such as direction and gradient of groundwater flow.

3. Characteristics of cover material - The soil used as cover material shall be of such character that it can be compacted to provide a tight seal, does not crack excessively when dry, and is free of putrescible materials and large objects. A 25 pound sample and details as to source may be required with each initial application, and renewals.

4. Water Pollution - Sanitary landfill operations shall be limited to areas where water pollution will not create a health hazard. Provision of a seal between the refuse and the water table which is satisfactory to the Department may be required.

5. Equipment - Adequate numbers, types, and sizes of equipment shall be used in operating the landfill in accordance with good engineering practice and with these standards. A list of equipment will be required with each initial application and renewal.

6. Plans and specifications - All sanitary landfills shall be designed in accordance with these standards by a professional engineer.

Detailed plans, specifications, and necessary reports shall be submitted by the engineer to the Department for review, approval and file. Any proposed alterations or deviations from these plans must also be submitted for approval and file.

Section 2 - Preparation of the Site

1. On-site roads - On-site roads shall be designed and constructed so that daily operating traffic will flow smoothly and will not be interrupted by ordinary inclement weather. They must be suitable for carrying traffic in all seasons.

2. Employee facilities - Suitable shelter and sanitary facilities shall be provided and maintained for personnel.

3. Communications - Telephone or radio communications shall be provided at the sanitary landfill site.

4. Measuring facilities - Means shall be provided for obtaining accurate measurement of refuse delivered to the site by weight and/or volume.

5. Fire protection - Suitable measures acceptable to the Department and other responsible authority shall be taken to limit and control fires.

Section 3 - Operations

1. Limited access - Access to a sanitary landfill shall be limited to those times when an attendant is on duty and only to those authorized to use the site for the disposal of refuse. Access to the site by unauthorized persons shall be restricted by suitable fencing.

2. Receptacle - A receptacle shall be provided outside the gate to receive refuse from households during the periods the site is closed.

3. Unloading of refuse - Unloading of refuse shall be continuously supervised by the operator of the disposal site.

4. Blowing paper - Measures shall be provided to control blowing paper. The entire area shall be inspected and tidied regularly.

5. Spreading and compacting of refuse - Refuse, except as exempted in Item 14, shall be spread so that it can be compacted in layers not exceeding a vertical depth of 2 feet of compacted material.

6. Compaction - Compaction will be carried out to achieve an average apparent density in pounds per cubic foot satisfactory to the Department.

7. Volume of cells - Each cell consisting of one or more compacted layers shall not exceed the maximum 24 hour quantity of wastes.

8. Daily cover - A compacted layer of at least 6 inches of approved cover material shall be placed on all exposed refuse by the end of each working day.

9. Final cover - A layer of approved cover material compacted to a minimum thickness of 2 feet shall be placed over the entire surface of each portion of the final lift as soon as possible following the placement of refuse within that portion, so as to prevent fly emergence and rodent infestation. In no case will the delay be longer than one week following the last placement of refuse in the cell.

10. Maintenance of cover - All final cover must be maintained for a period of two years in such a manner as to prevent fly emergence and rodent infestation.

11. Equipment maintenance - Provisions shall be made for the routine operational maintenance of equipment at the landfill site and for the prompt repair or replacement of landfill equipment.

12. Sewage solids or liquids and other hazardous materials - Hazardous materials, as listed in appendix "C" shall not be disposed of in a sanitary landfill unless special provisions are made for such disposal through the Department.

13. Large items - Provisions shall be made for the disposal of large, heavy, or bulky items which lie within the capabilities of the site, as established by the registered licence holder or operator.

14. Burning - No garbage or refuse containing garbage or other putrescible material shall be burned at the sanitary landfill. Burning of select materials shall be severely restricted, and shall be conducted only with the permission of the Air Pollution Control Service.

15. Salvage - When salvaging is permitted, it shall be so organized that it will not interfere with prompt sanitary disposal of refuse or create unsightliness or health hazards. Scavenging shall not be permitted.

16. Insect and rodent control - Conditions for the prevention of insects and rodents shall be maintained by carrying out routine landfill operations promptly in a systematic manner. Supplemental insect and rodent control measures shall be instituted whenever necessary in the opinion of the medical officer of health.

17. Dust control - Suitable measures shall be taken on the site to control dust where this appears necessary in the opinion of the Department.

18. Drainage of surface water - The entire site, including the fill surface, shall be graded and provided with drainage facilities to minimize runoff onto and into the fill, to prevent erosion or washing of the fill, to drain off rainwater falling on the fill, and to prevent the collection of standing water.

19. Sub-surface drainage - Where necessary in the opinion of the Department, sub-surface drainage, collection and disposal of drainage in a manner satisfactory to the Department may be required.

20. Completion of landfill - An inspection of the entire site shall be made by a representative of the Department as to comply with the approved plans and specifications before the earth moving equipment is removed from the site. Any necessary corrective work shall be performed before the landfill project is accepted as completed.

21. Supervision of operation - A landfill operation shall be under the direction of a qualified individual. Said minimum qualifications to be established by the Department.

22. Animals - Domestic and wild animals shall be excluded from the site.

23. Inspection and evaluation - Routine inspections and evaluations of landfill operations shall be made by a representative of the Department. A written notice of any deficiencies, together with any recommendations for their correction, shall be provided to the Registered Licence Holder or operator responsible for the use of the land; and the appropriate individual, firm, or government agency responsible for the landfill operation.

24. Operational records - A daily log shall be maintained to record operational information, including the type and quantity of refuse received. Upon completion of the landfill site a map shall be filed with the Department showing the depth of fill, type of fill and location of hazardous material, as provided for in Item 12.

Municipal and Industrial Incinerator Standards

Section 1 - Design

1. Drawings and specifications, including site location, shall be submitted to the Department for approval. These shall be prepared by a Professional Engineer.

2. Plans will include details of routes to be used for hauling of raw refuse and ash disposal.

3. The submission will include projected tonnage and volume of raw

refuse and of incinerated ash.

4. The submission will include details of storage capacity and projected maximum and minimum daily tonnage, and volume of raw refuse to be processed. The number of hours of daily operation will also be projected.

5. The submission will include an estimate of the qualitative and quantitative composition of the raw refuse.

6. Details will be submitted with respect to any scheme of salvage.

7. Information will be submitted with respect to staff, showing total of employees and distribution as to shift work and duties.

8. The drawings will include details of sanitary arrangements for personnel, including washing and locker faci ities and lunch room arrangements.

9. The drawings will include information respecting facilities to obviate air pollution as defined by the Air Pollution Control Act.

10. The submission will include information respecting facilities to obviate water pollution as required by the Ontario Water Resources Commission Act.

Section 2 - Operations

1. Incineration will be carried out in a manner such that the chimney effluent will be in accord with the regulations under the Air Pollution Control Act.

2. Storage of raw refuse will be under such conditions as to not develop a public nuisance, nor an unsightly appearance. Effective practices will be employed to control insects and rodents.

3. Incineration will be carried out to an extent that the organic and combustible content will be essentially completely consumed. The incinerator ash will be inspected and graded by the Department. Grade "A" will be accepted for use as open landfill, or for consolidation in land reclamation from water sites. Grade "B" containing incompletely oxidized or consumed putrescible matter will be restricted to sanitary landfill sites and procedures.

4. Proposals with respect to disposition of incinerator ash and other residues, and salvage will be submitted to the Department for approval in advance of their adoption.

5. Monthly reports will be submitted to the Department showing the disposition of incinerator ash with respect to tonnage, and location of disposal site.

6. Incinerator ash will be transported in covered trucks, with no spillage or leakage of quench water.

Composting Standards

To be issued.

Municipal Garbage Grinding Standards

To be issued.

# APPENDIX B

## BIBLIOGRAPHY

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# APPENDIX C

RELEVANT INFORMATION

# SUMMARY OF SOLID WASTE PROGRAM
## CONTRACTS
## US Dept of Health, Education & Welfare

1. Literature Survey of Public Health as Related to Solid Wastes
   Contract No. PH 86-66-151 Cost: $59,310
2. An Identification Program For Solid Wastes Research
   Contract No. PH 86-67-126 Cost: $19,500
3. Development of Training Courses, Aids, and A Training Program For Public Works Officials
   Contract No. PH 86-66-146 Cost: $86.523
4. Status of Unit Operations And Processes For Solid Waste Disposal
   Contract No. PH 86-66-160 Cost: $57,265
5. Evaluation of Methods of Solid Waste Separation, Recovery, or Disposal
   Contract No. PH 86-67-265 Cost: $76,650
6. A Study of Improved Methods for Dismantling Railroad Freight Cars
   Contract No. PH 86-67-100 Cost: $50,000
7. Technical-Economic Study of Solid Waste Disposal Needs and Practices
   Contract No. PH 86-66-163 Cost: $156,375
8. Feasibility Study for Applying Jet Engine Technology to Refuse Incineration
   Contract No. PH 86-67-259 Cost: $134,000
9. Subscale Experiments on the Model-400 Combustion Power Unit (CPU-400)
   Contract No. PH 86-68-198 Cost: $331,810
10. Systems Analysis of Solid Waste Disposal
    Contract No. PH 86-67-254 Cost: $98,515
11. Production of a Motion Picture Film on Solid Waste Disposal
    Contract No. PH OS-DQ-66-109 Cost: $10,500
12. Oceanic Disposal of Solid Wastes and Industrial Sludges From 16 U.S. Coastal Cities
    Contract No. PH 86-68-203 Cost: $50,000
13. Study of the Occurrence and Persistence of Pathogens and Indicator Organisms in Refuse-Sludge Composting
    Contract No. PH 86-67-112 Cost: $81,550
    PH 86-68-143
14. Composting Dewatered Sewage Sludge
    Contract No. PH 86-67-103 Cost: $67,695

15. Abstracting of Selected Periodical Literature

    Contract No. PH 86-67-182 Cost: $75,335
    PH 86-68-194

16. A Study of Composting Technology and Compost Utilization in Europe

    Contract No. PH 86-67-13 Cost: $10,000

17. Solid Wastes Management in Germany; Report of the U.S. Study Team Visit, June 25-July 8, 1967

    Contract No. PH 86-67-257 Cost: $2,000

18. Feasibility Study on the Disposal of Polyethylene Plastic Waste

    Contract No. PH 86-67-274 Cost: $63,485

19. Economic Evaluation of Converting Solid Waste Materials into Yeast

    Contract No. PH 86-67-204 Cost: $30,000

20. Study of the Cost of Municipal Incineration

    Contract No. PH 86-68-184 Cost: $32,570

21. Study of the Health Effects of Air Pollution Related to Solid Wastes

    Contract No. PH 86-66-129 Cost: $3,000

22. Construction of Continuous Chemical-Microbial Pilot Plant To Produce Edible Proteins from Cellulosic Wastes

    Contract No. PH 86-68-152 Cost: $74,230

23. Study of Packaging Materials and Waste Disposal

    Contract No. PH 86-67-114 Cost: $67,470

24. Investigation of Health-Related Differences in Microbiological Quality of Products From Various Types of Rendering Plants

    Contract No. PH 86-67-20 Cost: $60,265
    PH 86-68-126

25. Protocol for Undertaking a Research Program for on-Site Solid Waste Removal from High-Rise Residential Structures

    Contract No. PH 86-66-171 Cost: $10,000

26. Solid Waste Research in the Application of On-Site Refuse Storage, Collection, and Reduction System for High-Rise Residential Structures

    Contract No. PH 86-67-167 Cost: $160,575

27. An Examination of the Feasibility of the Recomendations in the NAS-NRC Publication, Waste Management and Control

    Contract No. PH 86-67-240 Cost: $140,580

28. An Action Program for Regional Solid Waste Management Systems

    Contract No. PH 86-67-290 Cost: $212,950

29. Study of Solid Waste Management in the Food Processing Industry

    Contract No. PH 86-68-138 Cost: $57,120

30. Determination of Airborne Emissions From Municipal Incinerators

Contract No. PH 86-67-62 Cost: $80,000
PH 86-68-121

31. Determination of Soil Index Properties of Cover Material and Sanitary Landfills

Contract No. PH 86-68-196 Cost: $13,550

32. Patent Search of On-Site Refuse Handling Devices for Commercial, Residential, Apartment, and Office Buildings

Contract No. PH 86-67-95 Cost: $1,750

33. An Appraisal of Current Refuse Collection and Disposal Practices in Western Europe

Contract No. PH 86-67-6 Cost: $450

34. Technical Feasibility of an Air Classification Process to Separate Selected Dry Solid Waste Materials

Contract No. PH 86-68-157 Cost: $20,000

35. Study and Evaluation of Technical and Economic Factors of Polymer Waste Disposal

Contract No. PH 86-68-160 Cost: $63,280

36. Engineering Study of A One-Man Collection System

Contract No. PH 86-67-248 Cost: $80,200

37. Solid Waste Management Study of the Automotive Assembly Industry

Contract No. PH 86-68-212 Cost: $55,880

38. Analytical Investigation of New Chemical Concepts for Waste Plastic Utilization

Contract No. PH 86-68-206 Cost: $99,930

39. Solid Waste Management and Rubber Refuse Potential in the Rubber Industry

Contract No. PH 86-68-208 Cost: $47,170

40. Development fo a Method of Prediction of Solid Waste Characteristics

Contract No. PH 86-68-97 Cost: $27,355

41. Survey of European Refuse Collection Practices

Contract No. PH 86-67-34 Cost: $600

42. Preparation of a Protocol for Codification and Data Gathering Survey to be Used by State Planning Agencies

Contract No. PH 86-67-12 Cost: $2,250
PH 86-67-43

43. National Industrial Solid Waste Management Study--The Printing and Publishing Industry

Contract No. CPE 69-6 Cost: $73,484

44. CPU-400 Program Management and Systems Engineering

Contract No. CPE 69-100 Cost: $175,832

45. Bureau of Solid Waste Management Annual Film Report: Progress in Solid Waste Management Through Research, Development, and Demonstration

Contract No. CPE 69-111 Cost: $100,475

46. Study to Determine those Factors Influencing Citizens' Attitudes and Responses to Factors and Solutions Regarding Solid Waste Problems

Contract No. CPE 69-107 Cost: $82,622

47. National Industrial Solid Waste Management Study--The Electrical Home Appliance Industry

Contract No. CPE 69-4 Cost: $31,720

48. National Industrial Solid Waste Management Study: The Drug Industry

Contract No. CPE 69-7 Cost: $80,000

49. Economic Study of Salvage Markets for Commodities Entering the Solid Waste Stream

Contract No. CPE 69-3 Cost: $103,193

50. Development fo a Digest of Existing Municipal, County, and Regional Solid Waste Management Ordinaces and a Model Solid Waste Management Ordinace

Contract No. CPE 69-114 Cost: $33,979

51. Conference on the Use and Disposal of Single-Use Items in Health Care Facilities

Contract No. CPE 69-102 Cost: $5,175

52. Investigation of Necessary Conditions for Proper Decontamination and Combustion of Organic Pesticides and Pesticide Containers

Contract No. CPE 69-140 Cost: $34,251

53. National Industrial Solid Waste Management Study--The Chemical Industry

Contract No. CPE 69-5 Cost: $90,964

# DEPARTMENT OF LANDS AND FORESTS

## CROWN LAND INFORMATION

## THUNDER BAY

The following information is a concise brochure of procedure and policy regulations governing the disposition of Crown land summer resort properties in Ontario for private or commercial use with particular reference to the Thunder Bay Forest District (prior to April 1, 1970, the area was known as the Port Arthur Forest District).

The district is presently zoned into three categories - open, deferred and closed. Sale is restricted to open zones only.

To determine the potential shoreline for disposition a land management plan is prepared for each lake. Although individual parcels are sold, the Department prefers to dispose of cottage sites within presurveyed plans. Under this system, suitable areas are first surveyed into groups of individual sites and each plan is given a registered number in the local Lands Titles Office or Registry Office before the properties are offered for sale. In every subdivision certain areas are reserved from sale to provide public access, and for any other purpose thought to be in the best interests of all concerned.

Under existing policy, applicants cannot be considered for any lands situated on waterways which are not accessible by a public road, rail or a direct water route. Generally, crown sites now being offered, are not directly accessible by public road, but rather must be reached by water from terminus of existing access roads.

### GENERAL CONDITIONS OF SALE

1. An individual must be 21 years of age or over.
2. Each applicant is allowed to purchase one site only.
3. Lots are sold on a first come first served basis.
4. Sites must be inspected personally prior to purchase - refunds are not permitted.
5. Private cottage parcels are usually sold in regular areas having from 100 to 200 feet of water frontage and being from 200 to 300 feet in depth.
6. The size of a commercial site for a regular area is restricted to a minimum of three acres and not larger than fifteen acres and having a width not under 300 feet and not over 1200 feet.
7. Application forms to purchase will be supplied upon request.

### CHARGES FOR LAND

The charge for land for private use is $250.00 plus $2.50 for each foot of frontage.

The commercial rate for each foot frontage is $4.00 plus $100.00 for each acres in excess of eight.

PATENT REQUIREMENTS

To obtain title, the applicants are required to construct a building on the location of at least 320 sq. ft. and up to $1800.00 in value within two years of date of payment of the purchase price for private use. Building requirements for commercial sites vary from a minimum of $3000.00

All lots sold in this district will be subject to either Municiapl or Provincial Land Tax. In addition school tax and/or local road tax may apply in some areas.

Maps may be obtained by writing and including the purchase price to the District Forester in any of the various forest districts of Ontario. The Thunder Bay District Office have maps for sale, including the following:

| | | | |
|---|---|---|---|
| #23 | Thunder Bay District | 8 miles to 1 inch | $2.00 |
| #24 | Kenora-Rainy River District | 8 miles to 1 inch | 2.00 |
| #25 | District of Cochrane | 8 miles to 1 inch | 2.00 |
| 52A | Fort William | 4 miles to 1 inch | 1.00 |
| 52B | Quetico | 4 miles to 1 inch | 1.00 |
| 52H | Nipigon | 4 miles to 1 inch | 1.00 |

| | | | |
|---|---|---|---|
| 52A/NE | Lac Des Mille Lacs | 2 miles to 1 inch | 1.00 |
| 52G | Ignace | 4 miles to 1 inch | 1.00 |
| 52I | Armstrong | 4 miles to 1 inch | 1.00 |
| 52A/NW | Kaministiquia | 2 miles to 1 inch | 1.00 |
| 52A/SW | Port Arthur/Fort William | 2 miles to 1 inch | 1.00 |
| 52A/NE | Black Bay | 2 miles to 1 inch | 1.00 |
| | Northern Light Lake | 1 mile to 1 inch | .60 |
| | Lac Des Mille Lacs | 1/2 mile to 1 inch | 1.50 |

Any maps sold within the province are subject to the Ontario Sales Tax.

Payment of all lots is requested in Canadian Funds. Cheques or money orders are to be made payable to the "Treasurer of Ontario" or the "Department of Lands and Forests".

Additional information may be obtained by writing to the District Forester, Department of Lands and Forests, 14 N. Algoma St., Thunder Bay, Ontario. Office hours are Monday to Friday 8:30 A.M. to 5:00 P.M. except during July and August when they are Monday to Friday 8:15 A.M. to 4:30 P.M.

For your further convenience, information may be obtained and applications filed at the Chief Ranger Headquarters, Armstrong, Ontario.

R. A. Baxter, District Forester,
Department of Lands and Forests,
THUNDER BAY, Ontario

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